

Requirement Engineering for Context Aware Applications: A Proceeding for Context Elements Identification and Representation

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Abstract. A few years ago, it seemed inconceivable to think about cars able to detect open doors automatically, with a device for speech recognition; besides, it was almost unbelievable to imagine houses that close their windows in case of rain, or heating systems that turn themselves on at a specific time, reaching certain temperatures; among other characteristics. However, nowadays it is almost natural to have these benefits at our disposal; even it is possible to abstract oneself about the hardware used for their implementation.

This fact is due to the technical advance, as well as to the raise of a new paradigm: Context Aware Programming. In other words, the development of applications aimed to react automatically towards environment changes. This type of application requires a representation scheme over the contextual information used.

This paper defines some guidelines connected to Requirement Engineering for these systems to operate. First, a context taxonomy is conceptualized, used as a guide for eliciting processes; then, definitions for “element”, “context attribute”, and “representation scheme” are presented. Finally, a procedure for eliciting and specifying context is proposed.

Keywords: Requirement Engineering, Context Aware Applications. Ubiquitous Computing. Context Taxonomy. Context Element. Context Element Representation.

1 Introduction

Context-aware applications surpass, in some sense, traditional applications, due to the fact that they greatly improve the user experience with the system, as well as they maximize companies' profit, owing to beforehand knowledge of user preferences, among other benefits.

Nowadays, the demands for Context Aware applications have grown exponentially, to the extent that traditional application have incorporated, although

not being fully context-aware, some kind of awareness towards specific context aspects.

Context-aware application usage comprehends different areas: domotic systems, immotic systems, e-commerce, and tour guide applications, among others. It is essential, in all these areas, an agreement on how to fit or apply Requirement Engineering for the development of these types of systems.

One of the questions that arise immediately is how to get the information regarding the specific context for an application; how to represent such contextual information and how to define contextual information correctly.

In (3) different approaches have been shown regarding Requirement Engineering for Context Aware Systems; also it has been examined the limited usage of formalisms associated to Requirement Engineering methods for this type of applications. On the other hand, despite the fact that the analyzed approaches promote different methods proposed by Requirement Engineering for these systems, none of them express these methods in an accurate manner, which leads to uncertainty and some challenge at the same time, in pursuit of the development of a new method for this type of systems.

The goal of this paper is to provide, through an adequate representation, a clear and concise idea about how to organize and how to specify the context for an application.

Section 2 explains the importance of evaluating application environment, and section 3 compares already existing (4), (5) and (6) context taxonomies. In section 4 a new taxonomy is proposed. Section 5 defines the concept of context element and attribute, and shows a representation scheme for context element. An integrated proceeding for context elicitation and specification is proposed; and a case of study about a domotic problem is presented in Section 6. Lastly, conclusions and future research are analyzed.

2 The Importance of Context Evaluation

Context, or contextual information, is defined as the specific information required for featuring environmental entities regarding the specific application. Also, the definition of "entity" comprehends objects, people, users, time, services, place, among other elements; that is to say, any characteristic of an entity belonging to the environment of the application that could be measured, including the application in itself (a sensor, for instance, is part of a system). It is worth noting that it is only relevant to analyze a specific part of the mentioned information.

The most significant aspect that characterizes a context-aware application is that it reacts towards the changing environment. Traditional developments react to this changes in an indirect manner, that is to say, that it is generally the user who has to inform the changes produced to the system through specific data input, to which the application reacts accordingly. On the other hand, context-aware applications react automatically to context or environmental changes where it should be used, through a response in accordance with the specific situation (3).

What is the relevance of context evaluation? If, aimed to a context-aware application, we could define all contextual information that influences it, it will be possible to predetermine application behavior, specifically the part that is context sensitive.

3 Context Taxonomies

It is generally wide-reaching, in evaluating the application context, the volume and type of information that makes up the environment. For this reason, it is useful for the analyst, in the eliciting phase, to divide the context in several parts or types, so that s/he will determine what contextual characteristics are relevant.

3.1 Dey and Schlit taxonomies

Dey [4] and Schlit [5] suggest three categories.

- **Computing context**, such as the network infrastructure, input-output devices, and available processors, etc.
- **User context**, which includes the user location, location of nearby people, and social situation.
- **Physical context** such as the lighting, noise level, or temperature.

In [7], it is added a time component to the above selection.

Time context, such as the time of day, week, year, etc.

3.2 Krogstie Taxonomy

However, the most encompassing taxonomy is the one proposed by Krogstie [6]:

- **Spatio-temporal context**, which describes attributes like time, location, speed, direction, and the social arena.
- **Environment context**, which describes entities around the user such as services, temperature, noise, persons, and networks.
- **Personal context**, which describes the user's physiological and mental states.
- **Task context**, which describes a user's explicit goals, tasks and actions.
- **Social context**, which describes the social aspects of the user, such as information about friends and relatives, as well as a user's role (such as 'at work').
- **Information context**, which describes the global and personal information space which is available.

3.3 Dix and Rodden Taxonomy

In [8] and [9] four categories are proposed:

- **Infrastructure context**, defined as the device and the supporting infrastructure used to develop the application. This includes the network bandwidth, reliability, I/O device.
- **System context**, characterized by a device's awareness of other devices, applications, and users, as well as the overall interaction of the (distributed) system as a whole.
- **Domain context**, the semantics of the application domain. This may include "personalization", where an application is sensitive to a user's identity, and presents different information, accordingly.
- **Physical context**, characterized by a device's awareness of its physical surroundings, whether it is embedded in a car or mobile phone, among other possible scenarios.

4 New Context Taxonomy Approach

Although taxonomy proposed in (6) is the more comprehensive one, it is too specific and tends to confuse the analyst regarding some categories, given that the personal and social context could be unified in one type of context (user context), due to the fact that both types mention user characteristics.

On the other hand, (4) and (5) provide a clear and non-ambiguous taxonomy, however, several features are omitted in their definition, such as the user physical and mental state; besides, within the same taxonomy, specifically in computing context classification, elements related to the computer science are included, instead of defining measurable characteristics, as provided in the rest of context classification.

Due to these reasons, it is relevant to propose the definition of a new taxonomy, based on taxonomy suggested by (4) and (5), owing to its simplicity and specificity regarding the features of context-aware systems. Besides, some important elements are provided by (6). Furthermore, an expansion of one of the defined types is proposed, as well as an exemplification, taking measurable characteristics from entities that make up the general context of the application, for the sake of criteria unification. These enlargements are put in their corresponding context types mentioned within this taxonomy.

4.1 New Taxonomy Definition

"Computing context" classification is extended, so that it comprehends the above mentioned aspects, features of concrete objects that belong to the application or that interact with it; such as, sensors, external applications, among others.

It has been decided to enlarge this classification due to the fact that every concrete device that cooperates with context-aware application, such as sensors, mobile phones, inherent application devices can be damaged or unavailable.

The classification "computing context" has been changed into "object context", so that this new name fits more accurately the concepts it describes.

Based on taxonomy provided in (6), and given that the user's physical and mental states trigger variants in his/her preferences, these variables are defined within the user context defined by (4) and (5), due to the fact that they were not included in this type of context.

A modification of the "environment context" classification is proposed, provided by (6), leaving only internet, cable, light, water, and heating services that interact daily with the user, which can influence the application context. Besides, the rest of the elements mentioned by (6) are deleted, since they are already described in the context of the proposed taxonomy.

Therefore, the new Context Taxonomy proposed is the following:

- **Object context**, which defines the state of the network infrastructure, input-output devices, available processors, sensors, among others.
- **User context**, which includes the user location, location of nearby people, user's social, physical and mental state.
- **Physical context**, such as lighting, noise level, temperature, possible flood, toxic fumes leakage, smoke, etc.
- **Temporal context**, which describes the day, week, year, among others.
- **Environment context** that encompasses, on one hand, service characteristics, possible damages, slowness, availability; on the other, characteristics related to external people, such as location, displacement, etc.

The purpose of this new Taxonomy is to facilitate the Requirement Eliciting process, since it aims at representing more accurately the elements to consider and to analyze, which affect the development of applications of this new paradigm: Context-aware paradigm.

5 Context Representation

In accordance with the processes proposed in (10), for the development of "traditional" software systems it is essential to build requirement specification, during the context-aware development it is necessary to have environmental representation at our disposal.

Bibliography proposed in (11), (12) and (13) partially describes some methods for Requirement Engineering as regards context-aware systems, although there is no clear and explicit reference over the ways to elicit and to represent the information in a previous phase to the running of the application (3).

With the goal to establish a representation for contextual information, it is proposed a definition and possible usage of a new set of concepts, so that the required information is available in a clear and precise manner.

5.1 Context Element, Context Attribute and Value

"Context Element" is defined as any environment element of the application, that is to say, any adjacent entity, whose characteristics somehow influence the

application behavior. In other words, every tangible or intangible object, within the physical environment of the application, that cooperates or interacts with it, and whose characteristics, if modified, affect the performance of such application, is defined as “context element”.

“User context” is a typical example describing context element.

“Context Attribute” is defined as every measurable characteristic of a Context Element. A context attribute belonging to user’s context element could be the user’s religion.

Lastly, “Value” constitutes the outcome of evaluating the “context attribute” given a “context element” in particular. For instance, the religion “attribute” for the user’s context element could be Catholicism, Judaism, Buddhism, among others.

5.2 Representation Scheme for Context Elements

Figure 1 shows the proposed Representation Scheme for Context Element, where the number of Context Element is a number that allows to identify the rest of the elicited Context Elements. “Type of Context” corresponds to a type of context within the suggested taxonomy of this paper.

The rest of the components, quoted in this scheme, belong to concepts previously defined.

N° of Context Element:	
Type of context	
Context element	
Attribute or characteristic	
Value	

Fig. 1. Representation Scheme for Context Elements

The aim of this specific format is to contain, in one repository, all the information of each context element elicited: the nature of the element, the type of measurable characteristic evaluated, the type of context within the taxonomy that is represented, and the value or level/scale of values from the characteristic analyzed. Thus, a concise, precise and understandable representation is obtained.

The choice of a tabular format is based on its expressiveness. Its simplicity and synthesis ability facilitate the understanding, both on the part of the analyst and other stakeholders, such as clients, users, etc., over the information necessary to specify. Besides, language polysemy is avoided using this type of table, with less chance of error, since it is more precise and specific.

6 Integrated Proceeding for Context Elicitation and Specification

Based on the above mentioned concepts, that is to say, the proposed taxonomy and the representation scheme, an integrated proceeding that allows identifying and representing context elements is described.

According to (10), Requirement Engineering process involves the implementation consisting of three stages: **Requirement Elicitation** (knowledge acquisition), **Requirement Specification** (representation and synthesis of the obtained knowledge), and **Requirement Validation** (agreement).

The proposed proceeding comprehends the first two stages of (10); on one hand the defined Context Taxonomy is integrated with an *ad hoc* questionnaire, so that context elements from an application are obtained; then, the interview with the client is carried out following this questionnaire, thus obtaining the necessary information regarding context and element.

Subsequently, the elicited elements are represented, following the representation scheme of context elements, thus obtaining a unified representation of elicited elements.

Such proceeding is represented in Figure 2

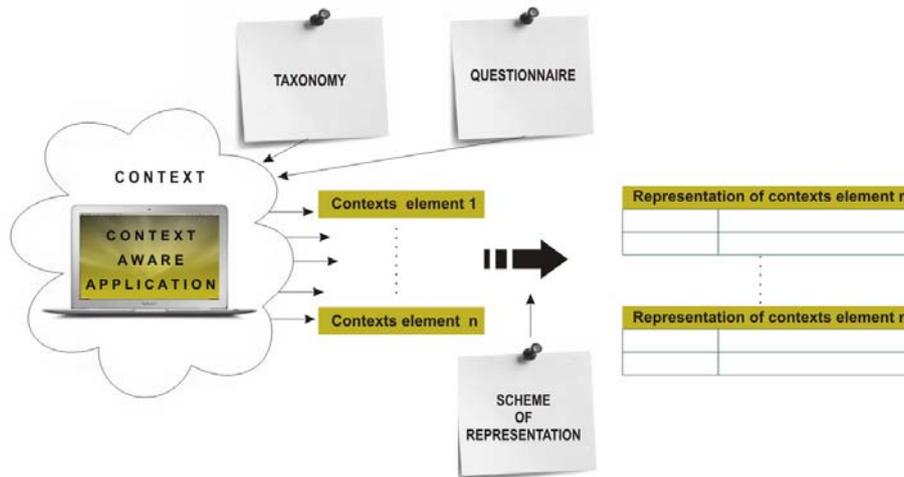


Fig. 2. Integrated proceeding for context elicitation and specification

6.1 Application for Domotic Systems

The following paragraph is a hypothetical situation regarding this problem domain, then, the observed elements are represented.

“A client requests a system for turning his/her house into an intelligent house, so that s/he can see what happens inside it, whether s/he is in the house, or outside, say, at work. Besides, the client wants the house lights that automatically switches on and

off when a person enters and leaves a room; that the garden waters automatically every day, at a certain time; room temperature regulate itself reaching a maximum of 24°C, approximately. Lastly, the client wants that during holiday periods, lights and television sets switch on and off periodically, and windows open and close automatically so that the house seems in use, and thus, the owner prevents burglary”.

6.1.1 Context Elements from Domotic Problem

In the following figures, examples of context element are described, which are the result of the above mentioned domotic problem, belonging to the five classifications stated in the taxonomy proposed in 4.4.

N° of Context Element: 1	
Type of context	Object context
Context Element	Water pump
Attribute or characteristic	State
Value	On/Off

Fig. 3. Element of Object Context

Figure 3 corresponds to the context element, **Water Pump**, belonging to the classification **Object Context** stated in the already defined taxonomy; besides, the outstanding characteristic is its **State**, whose possible values are: **On or Off**.

N° of Context Element: 2	
Type of context	User Context
Context Element	User
Attribute or characteristic	Presence
Value	Yes/No

Fig. 4. Element of User Context

In Figure 4 the elicited context element corresponds to the classification of **User Context** from the taxonomy, the element or entity over which certain characteristics are measured is the **User**, whose relevant characteristic is the user **Presence** and its possible values are: **presence (Yes); absence (No)**.

N° of Context Element: 3	
Type of context	Physical context
Context element	Environment
Attribute or characteristic	Temperature level
Value	-30 °C to 45 °C

Fig. 5. Element of Physical Context

Figure 5 represents context element called **Environment**, belonging to the classification of **Physical Context** from the taxonomy, and the relevant characteristic is the **Temperature Level**, whose possible values are from **--30 °C to 45 °C**.

N° of Context Element: 4	
Type of context	Time context
Context element	Time instant
Attribute or characteristic	Specific Time
Value	00:00 AM to 12:59 PM

Fig. 6. Element of Time Context

In Figure 6, the context element represented corresponds to the **Time Context** classification; the element or environmental entity over which certain characteristic is measured is **Time Instant**, and the relevant characteristic is, in this case, **Specific time**, whose possible values are from 00:00 AM to 12:59 PM.

N° of Context Element: 5	
Type of context	Environment context
Context element	Electrical system
Attribute or characteristic	Operation
Value	In operation/ out of operation

Fig. 7. Element of Environment Context

Lastly, Figure 7 shows context element **Electrical System**, belonging to the **Environment Context** classification; the relevant characteristic is **Operation**; whose possible values are **In Operation** or **Out of Operation**.

7 Conclusions

This paper is the continuation of (3), where several approaches regarding Requirement Engineering for Context Aware applications were presented and discussed.

Context taxonomies were analyzed briefly, and less ambiguous and more precise taxonomy, aiming at context specification, was proposed.

Then, in order to represent contextual information the concepts of “context element”, “context attribute” and “value” were presented. Besides, a tabular scheme is proposed, aiming at representing these elements, since it can be used to carry out a specification with a unified criterion.

Finally, this proposal is complemented with the introduction of a proceeding for the identification and representation of contextual information, showing its application in a real case study regarding domotic domain, using as an elicitation technique an **ad hoc** questionnaire.

The introduced concepts, together with the proposed procedure, constitute a novel contribution for the Requirement Engineering for Context-Aware Systems.

In conclusion, although this particular area of Requirement Engineering is in its maturation stage, new tools for its development were proposed.

8 Future Developments

Although this paper proposes a complementary and traditional technique used for the eliciting process, that is to say, a questionnaire, other techniques could also be applied.

On the other hand, a specific technique for contextual information elicitation is in the process development, or at least heuristic approaches that help obtain all context elements for a specific application.

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