Towards a Context-Aware Service and Quality Multimedia Adaptation for Healthcare Applications

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ABSTRACT

In the healthcare domain, the quality management of urgent situations is very important. Currently, these situations are accessible on a wide variety of embedded sensors. The heterogeneity of such sensors and the diversity of user needs require management quality of service and adaptation to different critical situations (*e.g. diabetic coma*). In some previous publications, we have proposed a semantic generic metamodel for specifying rich contexts containing explicit constraints expressions with qualitative and quantitative information. In this paper we improve our previous proposal by using fuzzy-based technique for the identification of urgent situations that takes into account both quantitative and qualitative parameters. Extensive simulations of some well known diabetes case studies embedding our technique, improve empirically the benefits of our approach.

KEYWORDS

Fuzzy Logic, Context, Emergency situation, Quality adaptation, Context profil, Multi-platforms

1 INTRODUCTION

Recently, the World Health Organization emphasized that the future of e-Health depends on the ability to install a culture of mobile communication and quality in e-health services. The e-health services in a mobile environment have a critical role in creating user satisfaction. They are neither a uniform group, nor able to give consistently high service quality. Indeed they are significantly mobile embedded and limited (low bandwidth, power consumption, etc.) device has to firstly prevent interaction and mobility limitation. The heterogeneity of components regarding embedded sensors, CPU power, communication mechanisms (*GPRS*, *WIFI*, *Bluetooth*, *etc*.), speed of transmission as well as the media variety (sound, video, text and image). The heterogeneity of such applications and the diversity of user needs require management quality of service and adapatation to different urgent situations (*e.g. diabetic coma*).

In some previous publications, we have proposed a model, named *ArchRQMM* (*Adaptation Service Ontology*), for specifying rich profiles containing complex constraints expressions [7], [8]. However, with the exponential growth of available sensors, the diversity of users needs and the conditions under which they access data, identifying the relevant urgent situations for particulars users becoming a challenging task.

Currently, a fair amount of research has been conducted in order to management platforms [6] [10] [11]. These platforms generally adapt services in order to comply with dynamic context evolution. For that purpose, they generally exploit high-level context models in order to identify situations. Furthermore, when situations have been identified, they usually search and compose

several adaptation components that will perform in order to solve these situations. However, we have noticed that current platforms not take into account a semantic description of heterogeneous context data (*e.g. glucose sensors provide glucose level data whatever unit of measure*). (2) - none of them are portable, i.e., it is not possible to migrate a context model between different platforms without modifying multiple quantitative context values. (3) – none of them are expressing rich constraints. For instance, a user cannot specify the following constraint in his profile: "*If it is lunch time, remind me to take some medicines using fast audio contents*". In other words, current context models do not support some specific desired actions under several conditions.

In this paper, we improve our previous proposal by using fuzzy-based techniques for the identification of urgent situations (*e.g. diabetic coma*). Moreover, we specify rich contexts containing explicit semantic constraints with qualitative and quantitative information, description of context model based on service references. Our approach focuses on description of rich semantic constraints model explicitly and to facilitate the system architecture quality control with the continuous evolution of its context. The major contributions are to integrate the rich context models to facilitate the management of e-health mobile applications at run-time level.

The rest of this paper is organized as follows: Section 2 details our rich context models and quality adaptation process, while section 3 presents an overview of the proposed framework. Section 4 presents application scenarios handling our metamodel. Section 5 presents some related works. Finally, Section 6 concludes and presents some future works.

2 THE CONTEXT MODEL AND ADAPTATION PROCESSES

The general structure of Context-aware Quality – Model Driven Architecture (CQ-MDA) is presented in Figure 1 [9]. We consider the full software development cycle within MDA, i.e. from formulation of needs up to the code generation. The proposed structure consists in five levels representing CIM, PIM, Contextual Platform Independent Model (CPIM), Contextual Platform Specific Model (CPSM), and code. Each level is decomposed into three parts: the left part represents architectural artifacts and context concepts; the right part represents quality model and measurements done for these artifacts while the center part represents requirements. Two ways of using our metamodel are possible:

- The first one assumes that the software architecture quality metamodel is used for evaluating an architecture model. The architecture model is tested and validated with the semantic constraints defined by the metamodel. If the verified architecture model gets bad marks then the design process can be stopped or it can go back to the previous stage either to change requirements or to elaborate a better model.
- The second one, using software architecture quality metamodel considers the case when the metamodel is used for selecting the best architectural model from different choices. In this case the values of a metric are used to classify the models. A metric formula gives a mark for the architecture model. The values of the metric function are used to classify the models and to choose the suitable one and we select a first model if we have the same value.

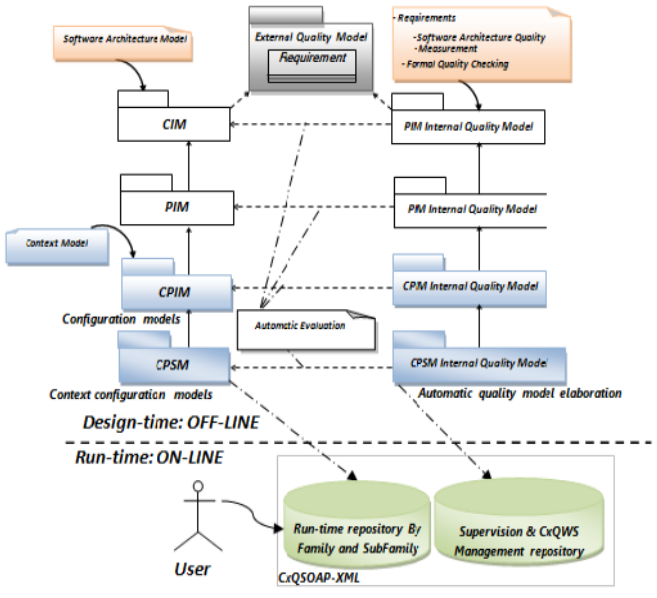


Figure 1. Context-aware Quality – Model Driven Architecture [9].

We extend the metamodel *ContextualArchRQMM* in [21] by adding *adaptation process families*, *rich explicit constraints* as new basic elements of the metamodel. We use adaptation process families from a preliminary analysis of the application at the design step in terms of QoS and update it in real time to meet the execution context and user's preferences. We consider that by incorporating semantic explicit user constraints concepts to *ContextualArchRQMM* we may be able to provide a method to specify adaptation rules over heterogeneous platforms (*smartphone, tablet, laptop etc*.) and sensors.

2.1 The Context Model

A context model should provide information about some hardware (device and sensor) capabilities, the user context and the document characteristics. Currently, context descriptions mainly contain static value (*size of the screen*) or dynamic (*battery level, preferred language, network bandwidth, glucose level, GPS coordinate s etc.*). However, if this type of context model migrates on different platforms, many context characteristics have to be reconfigured. An easy evolving characteristic is for instance a screen resolution or a set of available glucose units (*mg/dl or mmol/L*). Therefore, to ensure context model portability, our context model structure is based on service references.

To define a context model for *ArchRQMM*, we propose a hierarchy of three levels of abstractions. Fig. 3 illustrates a context UML meta-model. A low level of abstraction (M_0) contains the basic sensor services to define context model uniformly, like the *user location service, the glucose service, the battery power service*, the second level (M_1) holds functional ambient services and the third level (M_2) concerns with the facet services depending on the context used. Several hierarchies of services providing information may be constructed and consequently sets of services can be categorized into facets. Fig.2 shows three facets: *the context facet*, *the document facet* and *the hardware facet*. The relation between M_2-M_1 is necessary to improve context reasoning, taking decision and to give other information that can be used, whereas the relation between the M_1-M_0 levels is necessary to deal with the semantic of collected data and consider the change of the configuration of the service sensors.

We propose to express in such a profile rich constraints, like the following one “if the user location is located inside an area defined by some GPS coordinates and if the battery power level is less than 10%, turn off the sound of audio contents". As you can see in Fig. 3, our model is generic, it may handle several kind of explicit constraints with complex sets of disjunctive and conjunctive conditions. Consequently, our context model refers to services, we can migrate the context from platforms to platforms by preserving the constraints. Another advantage of this context model is that we do not need to update the model at any time, only specific services may be called for providing the only needed information.

In order to enhance our context model expressiveness, we have defined in the following a framework that bridges the gap between quantitative and qualitative information specified in context models. Adding qualitative terms inside context model is not straightforward. Indeed, a qualitative term, like "Low", may be applied on several context aspects, such as the device battery level, the glucose level, the bandwidth. Hence, the meaning of a term can be completely different depending on the context used. Moreover, even in a specific context, for several domains, a term may have different interpretations. For instance, the term "Low" in the context of the battery level corresponds to different quantitative values if we consider a smartphone or a laptop. This multi-level approach for bridging the gap between qualitative and quantitative information described in profiles is generic. Actually, this proposal may be used for a wide variety of qualitative terms. For instance, one may define qualitative terms for spatial information, such as “*close”, “far”, “intersect”*, etc. These qualitative terms may be attached to particular contexts, like location or surrounding devices.

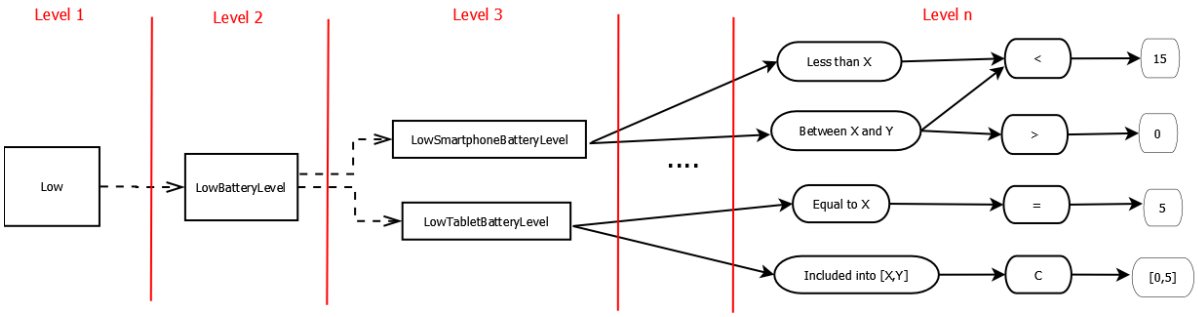


Figure 2. The multi-level approach that bridges the gap between quantitative and qualitative information.

2.1 A new context similarity measure

The ability of fuzzy expressiveness will give our system a fuzzy reasoning and help it to give the right urgent situation. The fuzzy logic is a powerful tool for reasoning, taking decision and to give other information that can be used. Rules in metamodel will be applied to properties, classes and the relation between the properties. Our research aims to improve the urgent situation identification of e-health applications.

In order to integrate other profile descriptions, we define semantic relationships between each pair of context concepts, such as *EXACT*, *SUBSUMES* (*i.e., the concept is specific/generic as another one*), *NEAREST-NEIGHBOUR* (*i.e., the concept is nearest neighbour of another*) and *FAIL* (*i.e., the concept does not match any concepts)*. When the situation identification is not possible, the identification can be done by replacing one or more context concepts by replacing it by another one (*or another set of concepts*) within the same facet or domain. Semantic relationships may be useful for the reaching a precision of situation identification. There are several possible ways to identify situation [6] [8], and a proper identifying *generic technique* still has to be defined. Computing similarities is also quite difficult when integrating heterogeneous user profiles. Several facet services composing a situation are generally connected semantically. Our similarity measure extends the properties of *Sim* defined in [6]. It is formalized as follows:

$$Sim(Q,S) = \frac{a}{a+b} = \frac{a\sum_{i=1}^{a} w_i * sima(Q_i, Sj)}{\left(a\sum_{i=1}^{a} w_i\right) + \left(b\sum_{i=1}^{b} w_{a+i}\right)} \qquad (1)$$

Where *"a"* is the set of common concepts of Q*i* (*current situation of user*) and S_j (profile *constraint*) for the same domain and *"b"* is the set of concepts of Q*i* and not existing in S_j. *sima* is the atomic similarity between each context concept of situation *Q, S*. It is defined as function that maps two concepts to the interval *[0, 1]*.

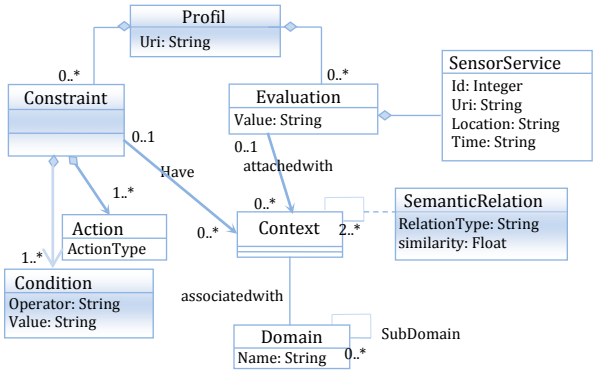


Figure 3. A semantic generic context metamodel.

2.3 Modeling the adaptation process

Performing adaptation processes at minimum time with minimum resources are always the most important purposes of users. Times included in this case are divided in to three groups: necessary time to analyze semantic constraints, processing length of time and decision making and finally time of adapted media transfert anticipating these times based on included criteria's in any adaptation stage and their performance is possible.

In our previous work [13], [14] we have proposed adaptation process metamodel. The adaptation process is defined as a (possibly infinite) set of finite adaptation paths, where each path defines a sequence of adaptation services in which the first

element in the path is the service of the current context, and the final element is a desired target service. Links between successive nodes in a path are associated with transitions that are selected from a set of multimedia adaptation services.
We can model the adaptation process as a (possibly infinite) set of finite adaptation paths, where each path defines a sequence of adaptation services in which the first element in the path is the service of the current context, and the final element is a desired target service. Links between successive nodes in a path are associated with transitions that are selected from a set of multimedia adaptation services. Our metamodel proposes to define adaptation family to capture a non-predefined number of adaptation paths having close adaptation services (see Fig.4). For example at image family which includes services offering services of the same nature (*i.e. image adaptation services*) but only differs by their adaptability to the context (e.g. adaptation time, transfert time).

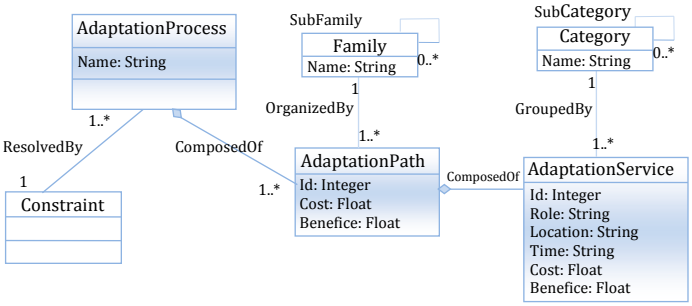


Figure 4. A semantic generic adapatation metamodel.

Our adaptation decision process uses a QoS function in order to select a quality adaptation path. From Eq. (1), we can observe that *QoS metric* is a ratio of weighted sum of benefits to that of costs of adaptation services. The QoS function is used for selecting the best adaptation path that has a higher ratio Benefice/Cost. In this case the values of a quality formula are used for classifying the relevant adaptation paths that have potential benefit. The evaluation of the adaptation paths having the same mark of benefice that maximize users' qualities (*expressed as preferences*). That will only modify the mark of the adaptive criterion (*response time, adaptation time, etc.*). So, selection is specified by analyzing finite sets of adaptation paths having the same mark of benefice metric and differs only by their adaptability cost to the context.

$$QoS(path) = \frac{W_{benefit} * \sum_{s \in path} Benefice(s)}{W_{cost} * \sum_{s \in path} Cost(s)} \quad (2)$$

Where $W_{Benefice}$ and W_{Cost} are weights associated respectively to the mark of benefice and cost. These weights cannot be set directly by the user. A user may specify in advance that the execution time is not a constraint and that he prefers a hi-quality video, and these weights are then computed automatically during the profile creation. All these weights are set between *[0, 1]*. The comparison of adaptation path scores allows us to select the best path.

3 ARCHITECTURE

The proposed framework offers two operations: the first one is the fuzzy context reasoning and the situation identification. This takes as input a high-level context model and then infer situation. The second one is how to determine which adaptation path needs to be made according to execution context or user preference. Fig. 5 illustrates the architecture of our framework on adaptation process and context-aware meta-models.

3.1 Context model building

The *Context Collector* collects low-level context informations from different distributed sensors, analyze and build the high level context model ❶ (Table 1).

TABLE 1. Sensor, Context and Interpretation

Sensor	***Contexts***	***Contexts values***	***Interpretation***
Glucose Sensor	*Glucose Level (mg/dl)*	*50*	*Very low*
Weight sensor	*Weight (calorie)*	*256*	*Very High*
GPS sensor	*Longitude Latitude*	*43°29.4201' 5°28.19000' 2013-07-28 09.30pm*	*City = 'Dubai' Location='Inside Home' Period = 'before Dinner'*

3.2 Situation matching

Each situation consists of two or more conditions. The conditions are joined with the AND operator. An example of situation rule is as follows:

IF *VeryLowGlucoseLevel* ***AND*** *VeryHighWeightLevel* ***AND*** *closeBayonneCity* ***AND*** *BeforeDinnerPeriod* ***THEN*** *UrgentDiabeticSituation*

The *Inference engine* (**Algorithm 1**) aims at matching the current situation with each constraint defined in the user's profile. It takes a list of current situation's concepts as input in order to calculate atomic similarity *sima* of each pair of concepts (of situation and constraint). If the match is not a *Fail*, it returns the overall score *Sim* of each constraints and appends the advertisement to the result set. Finally the result set is returned in ranked way. In so doing, we select the *higher* matching measure❷.

```
Algorithm 1 : Situation Matching
Input: Profile [], profile Status[], two
contexts C1 and C2 / C1 S and C2 Q
Output:
overall score Sim (Q,S)
matching relation (EXACT, SUBSUMES,
NEAREST-NEIGHBOUR, FAIL)

Step1: Get each constraint the atomic
similarity value of each common context
attribute (C1, C2).
Step2: Get each constraint an overall
similarity value defined in [1]
Step3: Return the higher matching score
with situation matching relation.
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3.3 Quality adaptation path decision.

As soon as an adaptation event is received (e.g., situation changes and/or user context changes), the *Adaptation Planner and Decisioner* will be able to evaluate adaptation path quality (*benefice*, *cost*) among a sub-family (or a family) that corresponds to a current situation and meets user preferences (*expressed as constraints*) and resource constraint (*CPU power*, *battery level*, *available bandwith*, *etc.*)❸. For example, suppose the following explicit constraint:

IF *UrgentDiabeticSituation* ***AND*** *LowBatteryLevel exclude videos* ***AND*** *include image instead*. This component translates this qualitative constraint into a quantitative constraint, e.g., *if my battery is less than 15%, exclude videos and include image instead for any mobile devices.* From a user context model and a current situation if we confirm that we must exclude videos and include images (because the current battery level is less than 15%), the adaptation process should start by evaluating and selecting an adaptation path form *video to image subfamily* (*video family*) under a valid device codec. Of course, the adaptation is customizable and parametrizable according to different device of users (*Tablet or Smartphone*). For instance, it may select an adaptation path that produces rapidly an adapted content with Samsung Smartphone under its implicit constraints (*device resolution*)

3.4 Call and run adaptation services. The *Executif runs* a sequence of transformation actions on the original media and provides an adapted media for each professional caregives ❹.



Figure 5. The architecture.

4. A DIABETES CASE STUDY

Our validation is based on the following case study. User A is an elderly patient who has been managing diabetes. Recently, he joined a persuasive telehealth trial study. User A has been provided devices (glucose meter, weight scale, video camera and GPS) to influence him to promote healthy behaviors. The profile information is utilized in aware to identify urgent situations. For example, the situation of "hypoglycemic diabetic coma'" is deduced by referencing the average of glucose level and weight in the profile (Table 2).

TABLE 2. Alert Situations

Condition	***Alert situation***
Glucose is 'very low' weight is 'very High' Location is 'Inside_Home' Period is 'before Dinner'	hypoglycemic diabetic coma
Situation is diabetic coma Walk is 'less'	Alarm

It will be very useful in our case study
To make better informed choices, help User A manage their situations in more practical way by User B (e.g. doctor), which has a Smartphone; video should be delivered in quality and in period no longer than one minute from their request.

4.1 Examples of scenarios

A first simple example is made of a user B which wants to share the elder's short video captured about 15 minutes using a Samsung Smartphone. There is atomic adaptation service that can fit the device constraint (*e.g. a low screen resolution of the Samsung Smartphone = 200 x 200 is inferior to the document pictures resolution 400 x 400*). The planner is used as a basis for finding adaptation services that matches the Samsung Smartphone context (i.*e. the less screen size*). Two re-sizing services: *a black and white picture* and *a coloured picture*. To limit the search results when browsing the elder's short video on the Samsung Smartphone, only the first one is returned that matches the *Samsung Smartphone* context (i.*e. the less screen size*) and the quality (i.e. *coloured picture*). A second scenario is when the adapted document is ready to be executed. User B receives a phone call to join his colleagues at the work. The analyzer has noticed a problem of bandwith, and the profile is dynamically maintained. Of course the user B wants to exclude audio during his work and include picture by using a specific codec (e.g. JPEG). This constraint "*sound excluded while user close to his office*" is an explicit constraint between a context information (*user close to work*) and a document (*audio and video sound not allowed*). In this situation, the analyzer checks the constraints of the user and interprets a close level of user location is longitude = 14', latitude = 25' and altitude = 40'. Then the planner looks for adaptation services that satisfy this constraint in order to make the adaptation chain. Several adaptation chains of *video to image subfamily* can be used to adapt elder's short video. Fig. 6 illustrates the search result of the best path preserving the shortest time and the quality image resolution. Consider the case shown in Fig. 6 again, path 2: *AVI→JPEG→PNG→JPEG* is a solution that solves the format constraint AVI and JPEG.

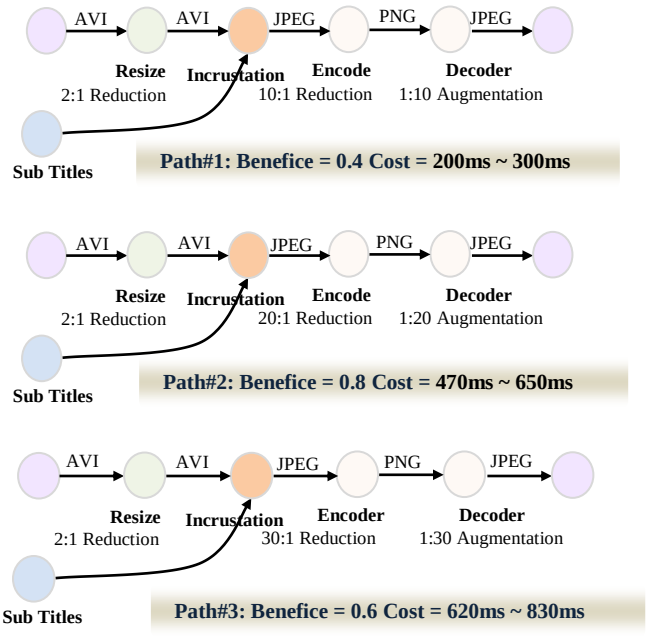


Figure 6. Classifying adaptation paths according to user quality preferences ($W_{Benefice} = 0.5$; $W_{Cost} = 0.5$).

This path is selected as the best path based on user quality preferences while the adaptation path *Resize→ AVI* is a solution that solves resolution constraint.

A third scenario, for instance when a current service delivers a high density color video, a notification was sent to the Analyzer that there is not enough available battery to continue displaying such a video. The ideal management on bandwith degradation is to follow a minor change by the replacement of a service (*Image Encoder/Decoder with High quality)* by another service (*Image Encoder/Decoder with Middle quality*).

4.2 Experimental evaluation

To show the relevance of our similarity measure, we have implemented algorithm 1 in Java and deployed on 3 heterogeneous platforms (Table 3). We consider about 10 persons will all properties of profile.

TABLE 2. Evaluation configurations

1. Android Smartphone connected Wi-Fi with RAM 512 MB processor (0.8 GHz)
2. Android 3.2 Tablet with 1GB of RAM a double heart Tegra 2 processor (1GHz)
3. Windows 7 laptop with 8GB of RAM and i5-quadrpule heart processor (2GHz)

The results obtained are reported in Figure 7 where we illustrate the response time between each user context and the various services. In Fig. 7, we compare the response time (adaptation time and transfert time) of elder's short video on three platforms (same context model). We find that the response time is four times faster in the configuration#3 using our adaptation strategy. These experiments allow us to consider the response time on three configurations with/without adaptation. We find our approach has a good performance in adapting the elder's short video using adaptation process families. Based on these experiments given in this section our approach improves the accuracy in comparison with techniques without adaptation. However, the platform seems to have impact on adaptation time. Thus, we want to continue, the evaluation of our quality adaptation technique on other platforms in order to define an optimized strategy.

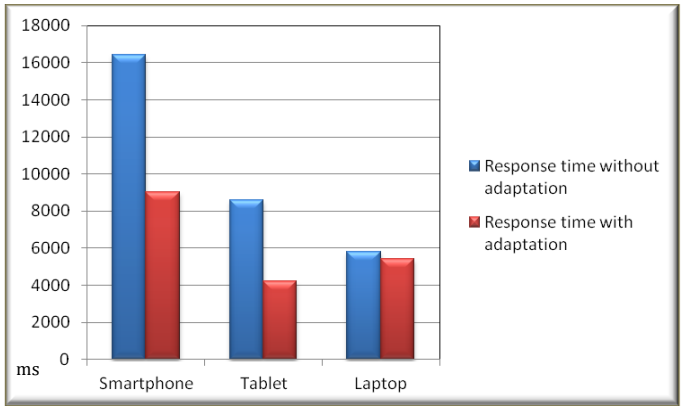


Figure 7. Response time under various platforms.

Now looking at results obtained by our fuzzy similarity measure *Sim*, the degree of the similarity is always high if the set of context attributes *(a)* suggested by the current situation of elder's and measured by sensors great, no matter the number of context attributes provided by the constraint and non measured by sensors.

The degree of similarity obtained *Sim* is more realistic and better reflects the correspondence degree between user profile and services. We can conclude that our measure depends on the atomic level of each context attributes and its weight. It also can be calculate the distance partially defined between profiles, i.e., there may be features in a profile that are not defined. It then exhibits more flexibility for the matching process.

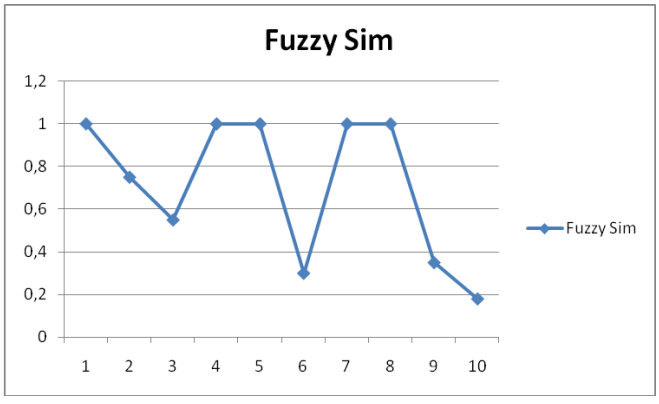


Figure 8. Similarity results under various profiles.

5. RELATED WORKS

The first related areas of research are smart home projects that have been proposed for monitoring of the elderly people at home [4] [5]. However, these works only have kept the focus under the old people welfare. Robles and Kim [12] concluded in their review that a main challenge of installing a smart home system is balancing the complexity of the system against its usability. In [7] a framework for assisting elders at home called ANGEHLA was proposed. That work has presented a solution based in a middleware that integrates a network of sensors and actuators such as: Cameras, Microphones, GPS, and Infrared etc. There is a central Human Interaction that monitors the elderly people and manages the members for aid situations. In emergency cases as fall, the elder will send a SOS message through a wearable device (RFID card) to the center. Then, the center gathers and sends members (unknown people are available) that are the closest to the elderly who needs help.

The second related area of research are some works involving adaptations of component-based applications refer to the capacity of a system to adapt to the evolving needs of the users and the context by exploiting knowledge on its configuration and the characteristics of QoS of its constitutive components. The adaptation based planning [2] and [1] is one of the adaptation approaches of component-based applications. Relevant work to our model is reported in [6] and [3]. Anagnostopoulos & al [6]. Introduces imprecise knowledge reasoning and decision making for determining and reasoning about the current situation. This work concentrate only on context-aware system architecture, while our proposal i)-provide multi-types model supporting, ii)- provide descriptive information and explicit constraints expressions, and iii)- provide quality context management in different mobile platforms. Compared to other work [3], our approach reasons about adaptation benefice/cost, deals with satisfying different user preferences, allowing users to best use context resources and restricting the of finite sets of adaptation paths that corresponds to situation identified from device sensing.

7 CONCLUSIONS AND PERSPECTIVES

In this paper, we propose to extend our previous proposal *ContextualArchRQMM* (Contextual ARCHitecture Requirement Quality MetaModel) [9], by adding adaptation process families and explicit constraints. The key notion of the approach is the new fussy similarity approach measure introduced that can be used for both quantitative and qualitative parameters. This enhance accuracy of urgent situation identification results by allowing divers kinds of attributes (either quantitative or qualitative) when describing user's profile and adaptation service profiles. At run-time, our framework copes with the challenges posed by the highly dynamic nature of mobile systems through continuous monitoring, identification of situation and calculation of the most suitable adaptation path. If a better path is found, the framework adapts at run-time the software, potentially via intelligent adaptation and mobility. We presented a diabetes case study to illustrate the applicability of the proposed approach. The experiment shows that our approach outperforms adaptation ratio and time response. In the future, we want to support the identification of urgent situation to meet complex constraints by multiple users with different profiles.

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