Chameleon – A Context Adaptive Visualization Framework for a Mobile Environment

Paulo Pombinho, Ana Paula Afonso, Maria Beatriz Carmo
Departamento de Informática, Faculdade de Ciências, Universidade de Lisboa
ppombinho@lasige.di.fc.ul.pt, {apa, bc}@di.fc.ul.pt

Abstract

The evolution of mobile devices, especially the integration of sensors, is fostering the development of context aware visualization applications. The adaptation to usage contexts is crucial to overcome the diverse limitations that exist in a mobile device, namely the screen size. However, most of the currently develop applications focus on specific contexts. In this paper we propose an adaptive visualization framework that has the goal of enabling the development of applications that use a diverse set of contexts and adaptation methods.

1. Introduction

The rapid evolution, on a global scale, of the telecommunication infrastructures has allowed the massification of users with access to wireless communication networks and to the mobile internet. According to the International Telecommunication Union report [1], mobile phone networks presently cover almost 90% of the world population, and it is expected that this number should reach 100% in 2015.

On the other hand, people increasingly feel the need to use, in a mobile environment, tools and applications that enable them to become productive in scenarios where they, previously, were not. This need can be seen in the circa 5 billion mobile network subscriptions and in the almost 2 billion people with internet access.

The conjunction of the growing desire for mobile productivity with the new available infrastructures, has been operating a change in our society.

While in the past, people planned and chose the various options of their day-to-day, in advance, often in the comfort of their home, they are now preferring to do it on the spot, in a mobile environment, using services or applications available in mobile devices. This need for more complex applications in a mobile environment can be seen in the growing demand for smartphones, which in some countries, in 2011, are expected to exceed the number of standard phones [2].

One of the features that has been fostered by advances in mobile phones and the, already frequent, integration of global positioning devices, are location based services. These services have gained much popularity because they allow a user to know, with some ease, what points of interest exist in their neighborhood (restaurants, hotels, and so on). However, despite extensive research with the aim of minimizing some of the limitations of the visualization of points of interest in mobile devices, there are still some unsolved problems.

The major limitation of a mobile device is its reduced screen space. Thus, whatever is shown onscreen has to be important to the user [3]. Moreover, the usability of these systems should be taken into account, since inexperienced users will not enthusiastically adopt these services if the complexity of the interaction and its restrictions are not removed [4, 5].

The adaptation to usage contexts is a key feature to mitigate the limitations in the usability of small screens. According to the definition of Reichenbacher [6], adaptive visualization concerns the adjustment of all components of the visualization process, such as the interface, the information extracted from the data and the data codification, according to a particular usage context.

With the growing amount of geo-referenced information available, the search for visualizations adapted to the specific usage context of each user will increase. The adaptive principle is especially important to increase the usability of the visualization of information in mobile devices and to reduce the cognitive load inherent to mobile usage contexts.

In recent years, the search for context-aware solutions has shown significant advances. However, research in this area has focused on computational contexts or device location context. Consequently, in the information visualization area, for mobile devices, the applications have explored only these contexts and the associated adaptations.

However, current context models and adaptive applications suggest richer and broader context dimensions beyond location and computation. The adaptation of information visualization techniques to other contexts has already been explored in some studies [6, 7, 8].

Despite the existence of some works that explore a larger number of different contexts, they are usually focused in a specific domain, making its reuse in other domains difficult.

The aim of this work is the creation of a framework that can facilitate the creation of adaptive applications for the visualization of points of interest that can deal with a diverse set of contexts and adaptation methods. To achieve this objective we adopt the classification and terminology adopted by Reichenbacher [6], and divide the main components of the visualization framework into adaptation objects, adaptation methods and usage contexts. The fundamental idea is to understand what adaptation methods adapt which objects depending on the different usage contexts present.

In the next section we will describe some of the related work. In section 3 we will review and categorize the different usage contexts, the adaptation objects and the respective adaptation methods. In section 4 we present our proposed framework and in section 5 we refer some case studies that have used this framework. Finally, in section 6, we present the conclusions and the future work.

2. Related Work

In 2001 Reichenbacher suggested an outline of a conceptual framework for adapting the display of geo-referenced information in mobile environments [9]. In this conceptual framework, the key elements identified are the user, the context and the current task. These elements should be responsible for adapting the visualization.

In 2008, Reichenbacher differentiates between adapted visualization, which is a display where tools are offered for changing the characteristics of the visualization, and adaptive visualization, in which the characteristics of the display are automatically changed according to the current usage contexts [6]. Reichenbacher identifies as basic building blocks of an adaptive visualization application, the context dimensions, the objects that can be adapted, and the adaptation methods. Thus, an adaptation method may receive one or more objects to adapt and use as adaptation parameters the values of the different contexts.

Bradley van Tonder and Janet Wesson [10], propose a model that incorporates an adaptive interface in the design of a map visualization system for mobile devices. Their model consists of four main components: A “Data Model” that contains the information that is being visualized in the system; a “Knowledge Base” that manages and obtains the four different types of context used (namely user profile, user task, time and location); the “User Monitoring and Modelling Component” that is responsible for accepting the user interaction data to try and automatically determine the user’s preferences and behavior; and finally the “Adaptation Engine” that manages the adaptations of the visualization (visual representations, detail level, zoom level), information (filtering) and interface (menu options).

Lastly, Panagiotakapoulos and Lymberpoulos [11] propose an active context-aware platform for the monitorization of patients suffering from special phobias. An ontology based context model was designed that used a diverse set of contexts to be able to provide a complete set of data that describes the current situation of the patient. The proposed framework is composed by six main components: “Context Providers” that are responsible for obtaining the diverse context data from the sensors and external sources; an “Aggregating Agent” that gathers all the data obtained from the context providers and analyses which data is useful; an “Inference Agent” that interprets the data from the previous component to generate high level contexts; a “Profile Agent” responsible for managing the profile information about the patients; a “Service Adaptation Agent” that queries the two previous agents to decide which actions should be taken; and finally the “Service Coordination Agent” responsible for managing the communication between the different agents present in the framework.

Despite the existence of the adaptive frameworks described, they are either too focused on a specific domain, making their reuse in other domains very difficult, or they do not have in consideration the diversity and quantity of the different usage contexts that are possible to be obtained in a mobile environment.

Thus, it is necessary to create a framework that is sufficiently generic that it may be reused in different domains and that has different types of context in consideration.

3. Contexts, Objects and Adaptation Methods

To be able to develop a framework that can effectively manage the adaptation to different contexts, it is necessary to understand, in advance, what is the relationship between the different contexts available in mobile environments, the adaptation objects that typically exist in mobile point of interest visualization applications, and the different adaptation methods.

As an example to understand this relationship, suppose it is late at night and the user is searching for a gas station in a mobile application, the information that is presented to the user (the adaptation object) should be adapted through the use of a filtering function (adaptation method) that selects locations that are open at that current time (the usage context)

In the following sections we will present and categorize the contexts, objects and methods of adaptation that are the building blocks for the creation of the adaptive framework.

3.1. Mobile Environment Contexts

We have chosen to categorize context, using a combination of the categorization that were presented by [12] and [13], since it represents the most comprehensive categorization for mobile environments. Thus, we consider five categories: Computation Context, User Context, Physical Context, Temporal Context and Historical Context.

Next, we will describe the various context dimensions identified for each category (as illustrated in figure 1) and the approaches for acquiring these contexts. As we have already stated, the identification of the contexts are crucial for the process of adaptation of the visualization.

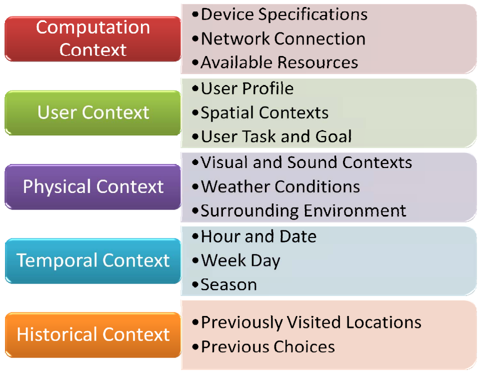

Figure 1. Context dimensions categorization

3.1.1. Computation Context. This category concerns all the technical features of the device, the device's connection to a network, and also the collection of possible resources accessible by the device.

The characteristics of the device can be automatically obtained during the applications installation. These specifications include the type and speed of the CPU, memory and storage capacity, screen size, resolution, number of colors, and also what input and output peripherals are available.

The characteristics of the network connection can be obtained in real time (for example, the available bandwidth) or specified by the user (for example, the cost of using the network).

3.1.2. User Context. The contexts directly related to the user include his profile, the user's spatial characteristics and the task he is doing.

The different characteristics of the user profile can be configured directly by the user, and include contexts such as age, language and nationality, experience in using the device and application, disability, and preferences.

One of the main contexts that, due to the type of use of mobile devices, is constantly changing, is the spatial context. The user's location has the potential to be the most important context in mobile visualization applications. This context can be obtained by a satellite positioning system like the GPS or inferred through the use of other integrated sensors. Equally important, the orientation of the user and therefore his focus of attention, can be obtained from a digital compass.

Other properties that may be important are the speed and acceleration of the user and the type of movement he is doing. This information can be obtained by analyzing the real-time GPS data and the information obtained from an accelerometer.

Finally, a crucial context is the knowledge about what task the user is (or will be) performing. This context can be specified by the user or automatically inferred by using information from historical contexts (described below).

3.1.3. Physical Context. The physical features surrounding the user can be divided into visual and sound conditions, weather conditions and surrounding environment.

The lighting conditions and noise levels at the location where the user is located may be obtained, respectively, through the device's camera and microphone.

Weather conditions can be obtained by combining different contexts: temperature, humidity, barometric pressure and intensity of ultraviolet (UV). This information can, in turn, be obtained in two different ways. On the one hand, it is possible to use a set of sensors (thermometer, hygrometer, barometer, and UV sensor) integrated on the device, that show the exact conditions in the location of the user. Alternatively, if it is sufficient to use approximate information, an online meteorological web service can be used instead.

The context of the surrounding environment can be obtained by analyzing, for example, the type of buildings (for example, public buildings, residential, factories or tourism), the surrounding terrain (for example, gardens, buildings, sea or mountain) or traffic conditions. In the case of traffic conditions, these can be obtained through the use of available online servers.

3.1.4. Temporal Context. These contexts correspond to the time of day, date, day of week, season of the year, among others. They can be obtained from the device's internal clock and calendar. Alternatively, online time servers can also be used to check if the date/time definitions are correct.

3.1.5. Historical Context. Lastly, the historical context of the previous choices made in the application can be obtained through the logs that were stored in the previous uses of the system. These logs may consist, for example, in the list of places the user has previously visited, previous queries, and also the different choices made by the user.

3.2. Adaptation Objects

Regarding the adaptation objects, we want to identify what objects commonly exist in a mobile visualization application that can be adapted depending on the different contexts.

The approach followed in this work is inspired by the proposal in [6], in which three distinct categories are suggested: Visualization, User Interface and Geospatial Information. This way, our categorization of the adaptation objects is as follows:

3.2.1. Information. Consists on the data presented to the user. It includes: the type of filtering done to the information, the amount of information that is presented, the ranking of their relevance and the area being considered.

3.2.2. Visualization. This category contains the graphical elements directly related to the information visualization in the device. For instance it includes: element codification (raster, vector), how the elements are arranged on the screen (positioning, size, color and opacity), the characteristics of the maps used (scale, orientation, legend, projection and center coordinates), its level of detail, the iconography used, and the use of generalization operators.

3.2.3. Interaction. Finally, the interaction category comprises the objects related to the applications interface. Includes: Use of different mechanisms or methods for the input of data, using different techniques for the selection of objects, moving the map and scale change operations.

3.3. Adaptation Methods

Finally, regarding the adaptation methods, these can be viewed as an association between the different contexts and the adaptation objects and are responsible for adjusting one or more adaptation objects. Thus, these methods can be classified, not only, in relation to the different categories of context, but also in relation to the different categories of object they adapt. This relationship can be seen in Figure 2.

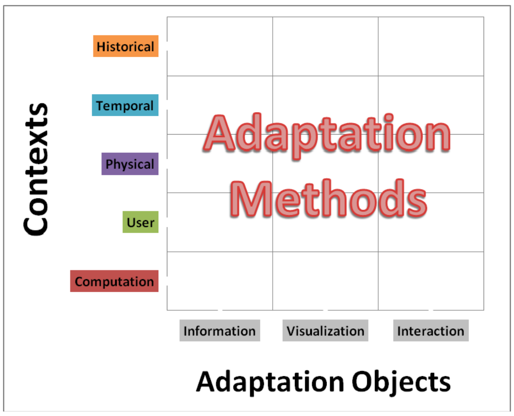

Figure 2. Adaptation methods categorization

For the sake of simplicity, the examples of adaptation methods, described below, are grouped by the context category they adapt to.

3.3.1. Computation Context. The knowledge of the characteristics of the device may enable the application to proceed with different types of adaptation: the computational load of the application may be adjusted by disabling more complex features if the device is a less powerful one; the detail and size of the icons used may be increased of reduced depending on the size and resolution of the screen; and alternate modes of interaction may be applied depending on the input and output devices available.

The network connection characteristics may be used to allow a better use of the available resources, through the use of a cache and by choosing the best time to obtain the needed data.

Regarding the cost of using the network connection, this information allows the application to know whether to give priority to speed (in case of billing by time) or to prioritize the reduction of the amount of data (in case of billing by amount of traffic).

Finally, the use of the information about the nearby available resources (printers, screens among others) may allow a better interconnection of the mobile devices with the different devices in its vicinity.

3.3.2. User Context. Concerning the user profile, characteristics such as age, language and nationality may influence the visualization used, adapting, respectively, the type of graphics used, the language and time definitions and the currency.

The type of interaction may also be adapted according to the experience in using the device and the application, the disabilities and the preferences of the user. Through these contexts it is possible to present more complex interfaces to the users, or more simple ones, depending on their needs and capabilities.

Lastly, the information presented can also be adapted according to the user interests, the locations he has marked as important (for example, his home and work place) and also cultural and social elements.

In relation to the spatial characteristics, the location context allows the application to show information about what is near the user. In the same way, the orientation context of the user can be used to show only the information about what is in front of him, or where the user is looking.

Properties such as speed, acceleration and the type of movement done by the user, may be used, not only, to calculate where the user is headed and to estimate how long he will take to arrive there, but also to adapt the way information is presented (for example, reducing the magnification of a map as the speed increases) or the type of interaction available (for example, using different techniques to select objects on the screen in the user is walking or running).

As already happens in systems like Google Latitude [14], the geographic proximity of friends and family can be used to assist the search for locations that are in the proximity of both users.

The knowledge about the task the user is engaged in is crucial to allow the presentation of the most relevant information that can be most helpful to aid the user.

3.3.3. Physical Context. Information about lighting conditions and noise levels present at the location where the user is standing are important to adapt the way information in transmitted to the user. The lighting conditions context can enable the application to adapt the colors used and the screen's brightness and contrast in a way that it can be easier for the information displayed to be correctly understood. Concerning the noise levels, it is possible to increase or reduce the volume of the device depending whether he is, respectively, in a noisy or silent location.

The information about the weather conditions can be used to show different information depending on the current conditions. If the user is, for example, looking for a restaurant, if it is a sunny day with comfortable temperature , the application may raise the relevance of a restaurant with a terrace, and the reverse if it was cold and rainy.

Using information about the surrounding environment it is possible to filter the information presented to the user taking into account such surroundings. If the user is near the sea the application could show beaches, or museums if the user is near a touristic area.

Traffic conditions can be, as is already done in systems like TomTom HD Traffic [15], used to suggest alternative information that avoids crossing locations that have traffic congestion.

3.3.4. Temporal Context. The temporal information may allow different types of adaptation.

The way the visualization of information is done (for example, the colors and icons used) can be altered depending on the time of the day (for example, using different colors whether it is night or day).

Using the local time context, it is possible to filter the presented information, taking into account the schedules of the locations and whether they are open or closed. Similarly, the presentation of information about events may take into account the current date and filter information that is still a long time away.

3.3.5. Historical Context. The analysis of the logs recorded over the previous uses of the application may allow, in combination with other contexts, to anticipate the needs of the user and automatically display the most relevant information at each moment.

4. Framework

To be able to make an effective management of the relationship between usage contexts, adaptation objects and adaptation methods, we propose the Chameleon, a Context Adaptive Visualization Framework for Mobile Environments.

This framework (Figure 3) consists of three main components, which correspond to the adaptation objects (in blue, on top), the adaptation methods (in green, on the middle) and the usage contexts (in red, on the bottom). The focus of our work is on the adaptation of the information and the visualization and not on the adaptation of the user interface. The modules that will not be focused on our work are presented with a black background.

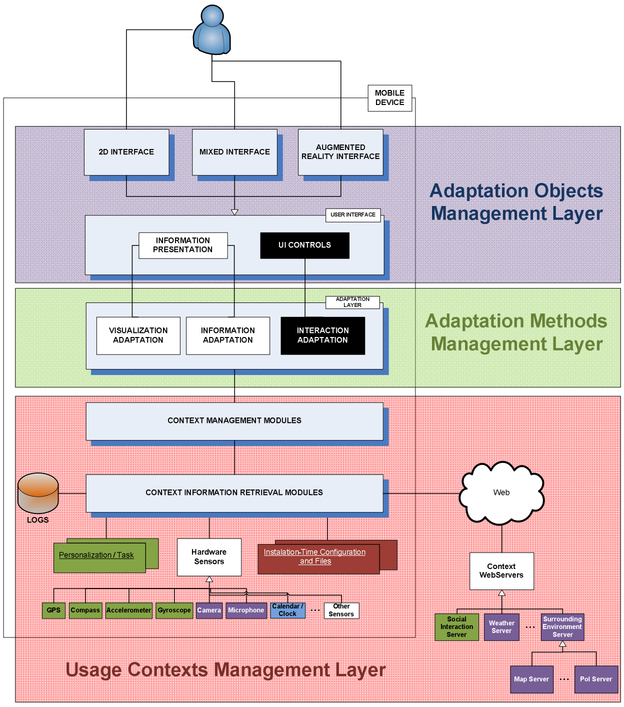

Figure 3. Chameleon Framework (detailed view of each layer in Figure 4, 5 and 6)

In the next subsections we will describe these three layers.

4.1. Adaptation Objects Management Layer

In the developed framework, the user can interact with three distinct primary interfaces (Figure 4): one consisting on a display of information on a 2D map representing the neighborhood of the user, another in which the information is presented using augmented reality techniques and, finally, a mixed interface in which a 2D map is presented simultaneously with an augmented reality view.

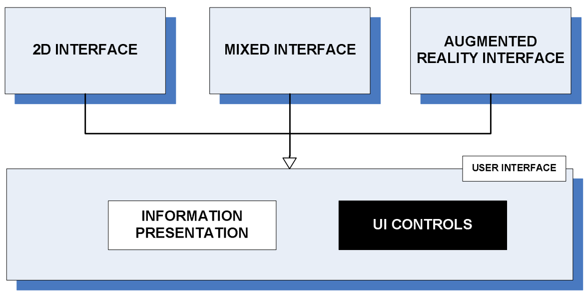

Figure 4. Adaptation Objects Management Layer

Thus, the elements that compose these distinct interfaces form the set of adaptation objects. For these, management is divided in two modules: User Interface Controls (which will not be the focus of this work) and the information presentation module (corresponding to the information and visualization categories of adaptation objects).

From a programmatic perspective, each adaptation object will be responsible for knowing and calling the different adaptation methods it relates to.

4.2. Adaptation Methods Management Layer

Regarding the Adaptation Methods Management Layer, it consists in three modules that manage the different types of adaptation (Figure 5). This way, the interaction adaptation module is responsible for managing the adaptations of objects directly related with the user interface control.

The information adaptation module and the visualization adaptation module will manage the information and visualization adaptations, respectively, requested by the adaptation objects that correspond to the information presentation module.

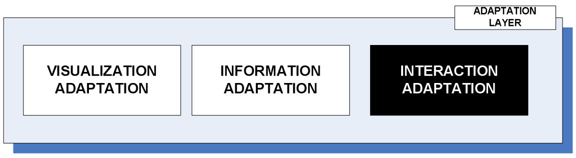

Figure 5. Adaptation Methods Management Layer

Thus, each adaptation method will be responsible for implementing different versions of the adaptations, allowing for some flexibility according to the type and value of the available contexts.

4.3. Usage Contexts Management Layer

Lastly, the layer responsible for managing the contexts is composed of two main sets of modules (Figure 6).

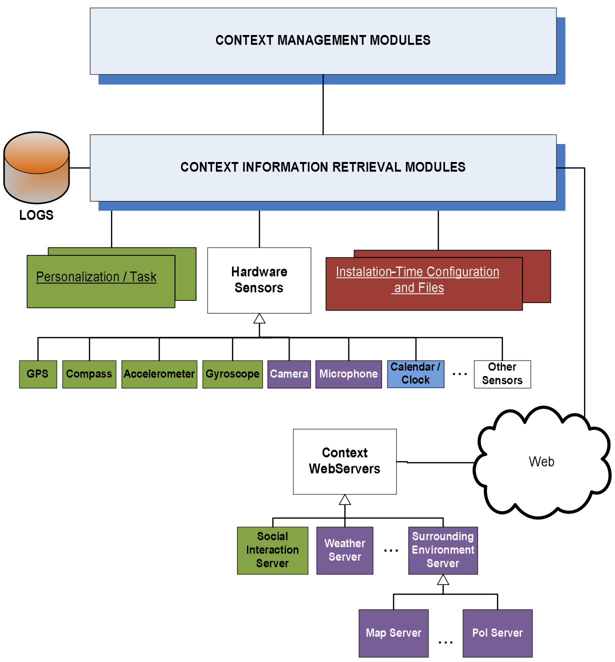

Figure 6. Usage Contexts Management Layer

The Context Management Modules are responsible for managing, calculating and communicating the contexts themselves. The Context Information Retrieval Modules communicate the required data to obtain / calculate the different contexts with the previous modules.

Regarding the latter modules, they are divided into five groups: an internal database in which historical records are stored, a set of dynamic files that contain personalization information and information about the user's current task, fairly static files created in installation time and configuration, a set of hardware sensors integrated with the mobile device and, finally, a set of context servers available via the Web.

Thus, the modules corresponding to each context should be responsible for obtaining the data required, from the Context Information Retrieval Modules, that allows them to calculate the value of the context.

4.4. Flow of Information

As an example of a possible flow of information, considering the adaptation of a map image to the location context: we have an adaptation object "Map" that will communicate with the required adaptation method, so that it may adapt the map picture to a new location.

This adaptation method will then request the "Location Context" module for its value. The "Location Context" module will then be responsible for asking the GPS sensor module the new coordinates or, if GPS is not available, use alternate sensors that may allow it to calculate the new location.

After obtaining the necessary information, the context module should calculate its value and return it to the adaptation method that called it. This method, after receiving the context information will then be able to adapt the map picture to the new location, returning it to the interface.

5. Application of the Framework

Parts of the proposed framework have been applied in some case studies that explore different types of usage contexts and some visualization and information adaptation methods that adapt some objects from the information presentation module. The different visualization applications developed are describe below.

In [16] an application for the visualization of points of interest on a 2D map interface was tested. This application used some adaptation methods that filtered the points of interest shown to the user depending on the location context and the user's search preferences, to show only the most relevant ones. Additionally, the icons were also adapted, taking into account the relevance of the points of interest associated with them and their location relative to other icons, by changing their graphical symbols to represent more than one point of interest and also conveying the most relevant ones.

In [17] a location and orientation aware application for the search of points of interest in mobile devices that uses, not only the location of the user, but also his orientation was presented. The location and orientation contexts are obtained through the use of position (GPS) and orientation (digital compass) sensors.

The developed application uses an augmented reality interface and adapts the way the different points of interest (and their information) are shown, according to their relative orientation. The interface also includes a dynamic adaptation of the indication of the device's orientation, complemented with the capture of real time pictures, using the device's integrated camera.

Finally, the choice of which stored picture (for each point of interest) should be shown is adapted by automatically selecting the one that most closely resembles the user's current location and orientation contexts. The addition of these pictures helps the user to compare what he is currently seeing in the real world, and correctly identifying the shown point of interest.

In [18] we have presented a point of interest aware application that uses the user's indoor location context to adapt the information displayed about the points of interest that exist in the vicinity of the user. To be able to correctly identify the position context of the user, we have proposed an indoor positioning method that does not need previously installed physical infrastructures in a building. Furthermore, this approach does not need external sensors, avoiding the restriction of the user's natural movements when using a mobile device and walking indoors.

6. Conclusions and Future Work

In this paper we have presented a review of the different types of adaptation objects, adaptation methods and usage contexts that may exist in a mobile scenario and categorized them.

Using this insight, we developed an adaptive visualization framework that has the goal to allow an efficient management of the relationship between objects of adaptation, methods of adaptation and usage contexts.

The proposed framework is composed of three main layers that correspond and manage the usage contexts, adaptation methods and adaptation objects. This framework aims to be sufficiently generic so that it can be used to a very diverse set of domains, and also to allow the knowledge and use of the very diverse types of context that exist in a mobile use scenario.

Although we have already done some case studies that use parts of this framework, we still need to create it, in a more global approach. To do this, we intend to create a more complex case study that uses a diversified set of contexts, objects and adaptation methods.

Acknowledgements

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