A MDA-based Approach for Enabling Accessibility Adaptation of User Interface for Disabled People

Lamia Zouhaier , Yousra Bendaly Hlaoui and Leila Jemni Ben Ayed
Laboratory LaTICE, Higher School of Sciences and Technologies of Tunis, University of Tunis, Tunis, Tunisia

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Abstract: In order to eliminate accessibility barriers that may exist in the user interface at runtime, we propose, in this paper, to integrate accessibility into an infrastructure of adaptation of User Interfaces. Hence, we propose a model driven approach which consists of generating, automatically, accessibility adapted User Interfaces. To reach this goal, based on MDA principals, we develop different meta-model transformations to provide an adapted User Interface model according to received accessibility context information and a given non adapted User Interface.

1 INTRODUCTION

Accessibility is considered as a very crucial issue of research in Human Computer Interactions (HCI) as it requires more investment in terms of technology and investigation. This is due to the big requirements imposed by the diversity of disabilities, including visual, auditory, physical, speech, cognitive, language, learning, and neurological disabilities (ISO, 2008).

In fact, accessibility is quite difficult to achieve. This difficulty is due to diverse factors, including the lack of proper development methods, authoring tools and accessibility training for professionals (Miñón, 2013). To reduce this complexity, we need a generic solution which is compliant to disable user requirements and best accommodates their particular needs. Therefore, we propose a generic MDA-based solution of adapting application's interface to accessibility context. One of the principal advantages of MDA (OMG, 2001); (Vanderdonckt, 2005) is the capacity to cover all the domains used in information system. Moreover, the MDA separates Independent Platform Models (PIM) from Specific Platform Models (PSM) and concrete models. Therefore, PSMs and concrete models will be generated by automatic transformations.

In fact, when a disable user wants to accede to a service such as bank service or healthcare service offered by an application through the internet, but he/she doesn't dispose of his/her PC and he/she has only his Smartphone. In this case, the application must be adapted to the new situation of use. The new context includes the handicap characteristics, the location, the physical environment (noise, light), and the targeted plateform used. The application has to be able to detect the current state of context and the new context in the ambient environment. Hence, it has to determine what actions to take based on this acquired contextual information.

Recently, these problems have motivated various researches to define features for interface's adaptation according to the context change. However, few of them such as (Stephandis, 2001) (Abscal, 2011); (Peißner, 2012); (Manca, 2013) have investigated on adaptation to accessibility context but they have not proposed generic solutions.

Our contribution consists of developing a generic solution of accessibility-aware in a model based approach that combines a set of recommendations required by ISO 9241-171 (ISO, 2008) and WCAG 2.0 (ISO, 2012) and integrates them into an adaptation process as adaptation rules.

In fact, our approach starts by defining the accessibility context model and the given application UI model. Then, the accessibility context model will be mapped into an ontology model. The latter represents the semantics of the accessibility context defined by high-level context properties. These properties are acquired from sensors related to environment, platform and user. Moreover, the adaptation process, which has as input the accessibility context model and the application UI

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model, is based on these context properties which are considered as conditions of the model transformation. The output of the adaptation process is the adapted application UI model. As we follow the MDA principals (Vanderdonckt, 2005) (OMG, 2001), the new adapted interface is generated using a model transformation from the adapted application UI model relatively to a specific platform and implementation environment.

The remainder of this paper is structured as follows: in section 2, we present the most relevant existing works related to accessibility, adaptation and even the model-based approaches for the adaptation of the UI. Section 3 presents our accessibility context model. In section 4, we describe our approach based on model transformations. Finally, section 5 concludes the paper and presents our future research.

2 RELATED WORK

Several approaches [(Stephanidis, 1998) (Akoumianakis, 1999); (Thevenin, 1999); (Calvary, 2002); (Bouchelliga, 2010); (Lopez, 2003); (Bacha, 2011); (Abscal, 2011); (Zbaidi, 2011); (Brossard, 2011); (Peißner, 2012); (Bongartz, 2012); (Manca, 2013); (Minon, 2013a); (Oliveira, 2013) have been proposed in the field of adaptation of human machine interfaces to context.

Some works [(Stephanidis, 1998) (Akoumianakis, 1999); (Lopez, 2003)] have focused on accessibility problem. They have tried to give some solutions in specific domains of applications (web-applications, healthcare, assistive-live, etc.). However, no generic and improved solution has been proposed in these works. Also, in the area of accessibility, others works have focused on adaptation using assistive technology solutions, but this remains still insufficient with the progress of technology.

Different adaptation's approaches have been based on context-awareness mechanisms specifying disabled people (Stephanidis, 1998); (Akoumianakis, 1999); (Lopez, 2003); (Abscal, 2011); (Peißner, 2012); (Manca, 2013). Among these works, some have stressed on context capture (Dey, 2000) and others on adaptation (Thevenin, 1999); (Calvary, 2002) by the use of legacy architectures and artifacts to input context into application logic (Vale, 2008).

Few works have been focused on identifying generic solutions for generating adapted user interfaces to various combinations of context [(Thevenin, 1999); (Calvary, 2002); (Bouchelliga, 2010); (Bacha, 2011); (Brossard, 2011); (Bontagartz, 2012); (Oliveira, 2013); (Minon, 2013)]. Thevenin et al. (Thevenin, 1999); (Calvary, 2002) have proposed a novel technique of adaptation called plasticity. It is a recent and emerged method of adaptation which denotes the capacity of an interactive system to withstand to context variations while preserving usability. In order to support the end-user preferences, adaptations rules can be changed according to user's order. It results from a Situation-Reaction process where the situation denotes a context change that needs a reaction, and reaction denotes the procedures that the system and/or the user executes to preserve usability. However, the solution doesn't consider netheir accessibility context nor model-based solution of adaptation.

On the other hand, to generate accessible adapted User Interfaces (UI) according to the context's change, we can mention two principals' projects: AVANTI (Stephanidis, 1998) and EGOKI (Abascal, 2011).

AVANTI (Stephanidis, 1998) is the first project to employ adaptive techniques in order to ensure accessibility and high quality of interaction for all potential users. It put forward a conceptual framework for the construction of systems that support adaptability and adaptivity at both the content and the user interface levels (Stephandis, 2001). The distinctive characteristic of the AVANTI browser is its ability to dynamically tailor itself to the abilities, skills, requirements, and preferences of the end-users, to the different contexts of use, and to the changing characteristics of users as they interact with the system.

EGOKI (Abascal, 2011) is a system that generates accessible mobile user interfaces adapted for people with disabilities in order to grant them access to ubiquitous services. These interfaces are intended to provide access to ubiquitous services in intelligent environments. EGOKI dynamically creates an instance of the interface running on the user device. To adapt the interface to the user characteristics, it is necessary to take into account what the most suitable communication modalities are for each user, mapping them to the appropriate media.

EGOKI and AVANTI projects have not considered neither presentation of UI in the adaptation process nor new guidelines as ISO 9241-171 at design process of UI.

The accessibility of application interfaces should be considered at an early step of the application

development. Only few researches, such as works presented in (Abscal, 2011); (Miñón, 2011) (Manca, 2013), have been devoted to adapt the content, presentation or the navigation scheme of the user interface to users with special needs.

Although, the notion of context was defined long time ago, few works (Hachani, 2009); (Bouchelliga, 2010); (Bacha, 2011); (Oliveira, 2013) have considered it to be integrated into an application modeling. They have proposed model-based approaches for user interface‘s adaptation. The latter consists of generating the final interface which matches the new captured context.

Hachani (Hachani, 2009) has proposed a generic method for adapting the context sensitive user interfaces. He has developed generic and reusable transformation rules which are appropriate to all contexts of use. He has been interested to the adaptation of language and screen size to the platform. However, he did not give detailed description of each element of the context of use.

Bouchelliga et al., (Bouchelliga, 2010) have proposed a MDE approach for plastic HCI. UI adaptation has considered various aspects of context and has been based on parameterized transformation. The authors have provided meta-models of different contexts used in the approach to adapt the interface.

Bacha et al. (Bacha, 2011) have presented a MDA approach for UI that have considered the content personalization since early in the design stage. The idea is to define the information which can be personalized while designing the interface. But, this approach could not previously define all potential content personalization during the design time.

However, none of these studies have considered accessibility context into adaptation process using model based development using MDA.

3 ACCESSIBILITY CONTEXT

We start by defining what a context is Dey (Dey, 2001) has given a definition that is widely used in literature: “Context is any information that can be used to characterize the situation of entities (i.e., whether a person, place or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves”.

According to (Rhee, 2012), the main functionalities of a context model are (1) deriving higher-level environmental context knowledge from sensory input data, (2) providing knowledge to other modules of application, and (3) updating the knowledge on runtime.

Our context model has to cover all requirements in the accessibility. Hence, it must to be generic and useful for any domain and for any UI generation. Generally, a context is defined as a triplet (user, environment, plateform) (Thevenin, 1999) (Calvary, 2002) (Vanderdonckt, 2005) (Sottet, 2006). It is generated by context sensors which automatically observe the user and measure some relevant environmental parameters (noise, light, etc ...) relatively to his/her current situation within the interaction. Unfortunately, it is manually generated actually.

In our approach, we define the accessibility context through the following dimensions or elements:

A. *TechContext*: includes information related to the technologies used in the interaction namely platform (PDA, PC, phone, etc.), communication and software. Software information represents the software installed on the device which can be used as assistive technology or as sensors. While communication information represents any communication technology such as WiFi, Bluetooth, connection internet Network, etc.

B. *AccessibilityContext:* is mainly based on the user context (profile, disability, ability, history, preferences, etc.) and accessibility barriers faced by the disabled in interaction with the interface.

C. *EnvironmentConditions*: includes any contextual information of physical conditions (temperature, light, sound, pressure, etc. . .).

D. *Location*: specifies the location where the context is defined and created (absolute position, relative position, etc.).

E. *TimeContext*: determines the exactly time (hour, minute, second) and date when a context is changed.

Table 1 recapitulates all the presented accessibility context dimensions and their relative information.

4 A MDA APPROACH FOR ADAPTATING ACCESSBILITY CONTEXT TO IHM

The Model Driven Architecture (OMG, 2012) has gained attention from human-computer interface community due to its capability of code generation from abstract models to concrete models.

Therefore, we propose a model driven approach

Table 1: Context Model including Accessibility Context.

Context dimensions		Information	
Accessibility Context	**Handicap**	Profile (user identification)	
		Interests/preferences	
		User demographics data	
		Language skills	
		Disability	Static
			Temporary
			Type
		User state	
	Accessibility Barriers	Navigation	
		Presentation	
		Content	
		Modality	
TechContext		Hardware	
		Software	
		Network	
EnvironmentConditions		Noise	
		Light	
Location		Adress (street, postal code, city)	
		Absolute position, relative position	
TimeContext		Hour	
		Date	

for generating accessibility adapted application's interface. This approach improves the capacity of managing the context inside the adaptation process at runtime. It allows the integration of accessibility requirements into adaptation process and the generation of the final interface. Moreover, we propose the use of different transformations at different abstraction levels according to received contextual information about accessibility.

This approach aims to provide an infrastructure of automatic adaptation and generation of user interfaces based on application's user interface model and model accessibility context development. Figure 1 illustrates the approach steps:

1. Step 1: first, we provide an abstract view of the user interface using retro-engineering techniques. The abstract view represents a non adapted Platform Independent Model (PIM A). Then we reorganize all captured contextual information from different sources with considering accessibility context. In fact, we collect all information relative to the accessibility context to build a generic and robust accessibility context model which will be mapped to an ontology model in order to give semantic interoperability. We use an ontology model in order to manage high-level context properties acquired from sensors related to environment, plateform and user.

2. Step 2: we specify and use the adaptation process which transforms the interface model (PIM A), according to the ontology model and based on adaptation rules, to an adapted interface model (PIM B).

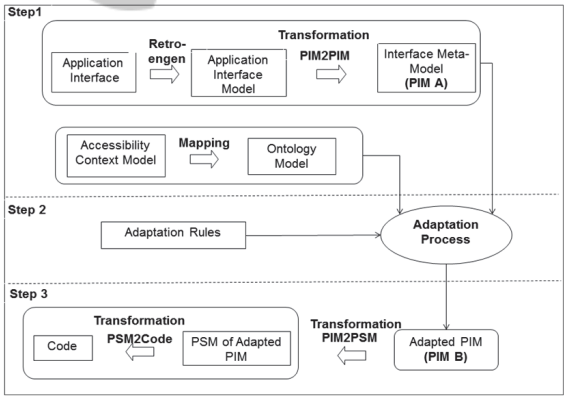

Figure 1: Model driven approach for adapting an accessibility context into a UI.

3. Step 3: using the adapted application model, which represents the output of the adaptation process, we generate the Platform Specific Model of the adapted UI (PSM) and then the relative code, depending of application platform, using simultaneously PIM2PSM and PSM2Code transformations.

4.1 Ontology-based Modelling of Accessibility Context Model

Context-aware applications are usually relied on a data structure or information repository called the context model. This model handles the processing and abstraction of contextual information. Context models were designed to describe contextual situations and to represent semantic relations between contexts in order to allow applications to make use of this information (Arrue et al., 2007).

Ontologies and contexts are both used to model views, which are different perspectives of a domain (Abascal et al., 2011). There is why our approach is an ontology-based context model. We define an accessibility ontology that organizes the knowledge of the domain and a context model to capture the information about the disabled user, platform and environment.

Ontologies support semantic mapping construction by providing explicitly defined meaning of the information to be exchanged (Arnarsdottir, 2006). Ontologies express conceptualizations (concepts, relations, and constraints) which are specific for a particular domain.

As figure 2 shows, we transform the information of the context model to an ontology model. The provided ontology specifies the knowledge about all accessibility requirements for all types of disabilities. This ontology is used as transformation conditions in our approach.

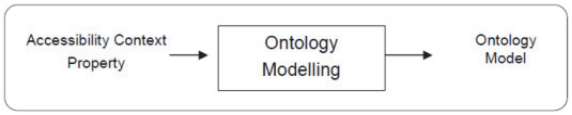

Figure 2: Creation of the ontology model.

After specifying the mappings between context's elements and ontology's elements, we integrate this correspondence within the User Interface Model.

As presented in (Happel, 2006) and (Paulheim, 2010), ontologies may be used at different points of time in the development process of user interfaces like:

- Design time: while developing the system. The ontologies typically are not a part of the user interface which is developed, and they are used to assist the developer.
- Runtime: when the system is executed. In this case, the ontologies most often become a part of the user interface and full a certain function in that user interface.

In our case, the process of adaptation must be performed at runtime. In fact, when a disabled user is requesting any application running into a giving device, the modeling of context model must be done at runtime. For that reason, it must be located in a local storage base as it will be transformed to an ontology model which will be used by the adaptation process.

4.2 Adaptation Process

Adaptation process is generally applied to a previously created user interface. However, in the case of adaptive systems for ubiquitous environments, the adaptation process is not based only on an existing user interface but also on an abstract description of the structure and an organization of the final adapted user interface elements. These elements are specified by the accessibility requirements captured from new context (Brossard, 2011).

Based on these results, we propose an adaptation process having as input (see figure 3):

1. Accessibility context event which triggers the process
2. Application interface model which is the subject of the personalisation and the modelling
3. Adaptation rules which represent the guidelines of adaptation to be applied.

The adaptation process has only one output which is the adapted interface model.

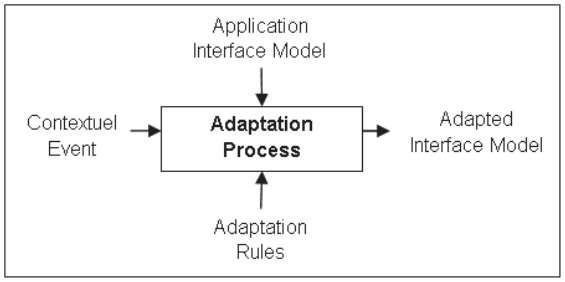

Figure 3: Input and output of the adaptation process.

To detail our adaptation process, we define in figure 4 the activity diagram specifying its different activities. The process is released when there are context's changing. At this moment, the time must be saved. In fact, at the arrival of the new context, an adaptation entity will be invoked in order to start the process at runtime. The context event triggers the process of adaptation by sending a request for rules to be applied to the actual situation given by the context and the interface model. Rules are divided into four subcategories according to the interface

elements namely modality, navigation, interaction, and presentation. Once the best rule is selected, an action of transformation will be performed.

As we follow the MDA principals in our adaptation approach, the adaptation process represents a transformation from an abstract interface model to another one which is tailored to the actual context. In fact, it includes the customization of interface design elements (such as Input/output fields, screen resolution, screen size, and so on) based on the context. This personalization is in reality the transformation from one element to another which determines different modalities customized to the user context.

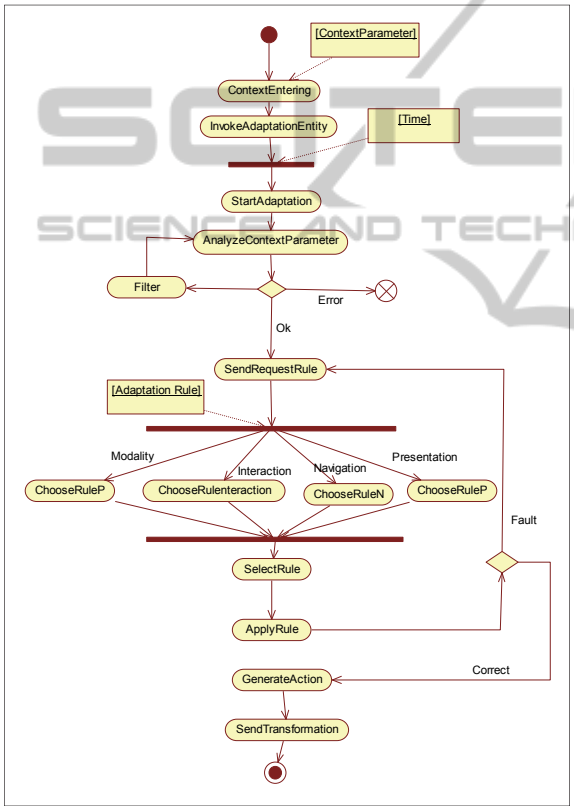

Figure 4: Adaptation process activity diagram.

4.3 Generating Final Adapted UI

Generating the final user interfaces in our model driven approach is an automatic process. The automation is necessary as the generation of the adapted should be in real time with the request of changing contexts.

4.4 Transformations

Transformation is a central concept in MDA to address how to convert one model into another model of the same application, and further into executable code (Arnarsdóttir, 2006).

In our approach, we invoke transformations at different levels (see figure 5):

- At adaptation process level: at this level, we define a PIM to PIM transformation. The PIM source represents the given application UI model and the PIM target models the adapted UI model.
- At generation process level of final user interface: on the adapted UI models, we apply, successively, a series of model transformations to provide automatically the final adapted user interface. These transformations are establisehed betwen the adapted UI PIM and PSM specific to the application platform and between this PSM and the Code reprsenting the the final adapted user interface.

Transformation enriches the models with the necessary and sufficient technical information needed. We have illustrated in figure 5 how we proceed with the different transformations of MDA paradigm from adaptation process.

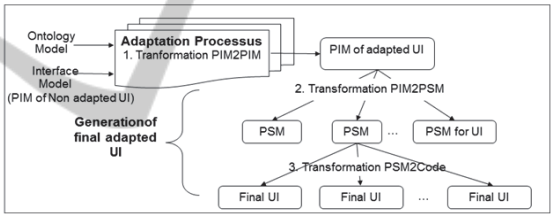

Figure 5: MDA Transformation in our approach.

In fact, the global approach could be summarized by a series of model transformations from initial platform to target platforms. Therefore, the originality of our generic approach is that it may provide different platform specific UI adapted models from one initial non adapted model.

5 CONCLUSION AND FUTURE WORK

In this paper, we have proposed a generic model driven approach for adapting application‘s user interface to the context change specially the context of disabled people. This approach proposes different transformations at different levels to generate adapted user interface. This interface is executed in a target plateform tailored to a given disabled user. In this approach, we consider accessibility requirements at runtime and at early design stages.

As further work, we will define a generic accessibility context model and specify an ontology domain which will be matched to the context model.

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