Adaptation to the Context in M-Learning Application Using Mobile Design Patterns

https://doi.org/10.3991/ijim.v17i06.36937

Lamia Hamza
Department of Mathematics and Computer Science, University of Oum El Bouaghi, Oum El Bouaghi, Algeria
hamza.lamia@univ-oeb.dz

Abstract—Today, E-Learning supported by the rapid increase in holders of mobile devices as smartphones, tablets or laptops, has progressed towards a new paradigm, that of Mobile Learning or M-Learning. The rapid evolution of mobile devices and the popularity of mobile applications in the market requires complex software to run easily on mobile devices. Mobile devices are known as handheld devices and have different features such as size, resolution and battery life. These are limitations to consider when developing mobile learning applications, which can make it hard to design and develop mobile applications for diverse mobile devices. Design patterns are a set of proven solutions to communal problems that were originally developed for desktop computers, so applying these patterns to mobile learning applications may not be sufficient for needs such as adaptation. Adapting content to mobile devices used by learner's environment. Nevertheless, mobile design patterns adapted or designed for such environments can be used to overcome the challenges and limits of mobile learning application development. This article we try to propose an engineering approach based on design patterns allowing the development of mobile learning applications. This proposed approach permits to offer an adapted content taking into account a mobile device context used by the learner. We named these patterns: "Mobile Design Patterns".

Keywords—design patterns, patterns engineering, reusability, mobile learning, adaption context

1 Introduction

1.1 Background

A design pattern is a characteristic arrangement of modules, recognized as good practice for solving a software design problem. It describes a standard solution, usable in the design of different software.

A design pattern comes from the experience of software designers. It describes a recurring arrangement of roles and actions played by software modules, and the pattern name serves as a common vocabulary between designer and programmer.

Corresponding to a design pattern in architecture, the design pattern describes the outline of a solution, which can then be modified and adapted as needed.

Design patterns describe general design processes and allow capitalizing on experience applied to software design. They influence the software architecture of a computer system.

Design patterns were formally recognized in 1994 following the publication of the book "*Design Patterns: Elements of Reusable Software*", co-authored by four authors: Gamma, Helm, Johnson and Vlissides (Gang of Four - GoF) [1]. This book, which became a best-seller, describes twenty-three "GoF patterns" and how to use them.

1.2 Motivation

The patterns provided by the Gang of Four [1] have an important influence on desktop application and software development. Design patterns provide proven solutions to recurring software design problems, making development process more competent and less time-consuming. Nevertheless, these design patterns were originally developed for desktop computers because the arrival of mobile computing had not yet arrived.

The progress of mobile learning systems and their environment presents new challenges and frontiers, such as, taking into account the need to adapt to the context of mobile devices, which makes the design of mobile learning applications different from ordinary computers.

Developers of mobile learning applications must consider various factors and new requirements that mobile devices and new technologies may bring. These problems can be treated by current solutions or by the proposition of novel solutions, i.e., mobile learning design patterns.

1.3 Problem

The development of learning systems for mobile devices is different from desktop computers because we have to consider several criteria to provide customized content to learners, such as, power consumption, battery life, distinctions in screen size, diverse kinks of user interfaces, multiple operating system and application type. Therefore, certain design patterns are not suitable for developing mobile learning applications. As mobile learning applications are more demanding in terms of performance and complex systems, design patterns for mobile devices are required.

1.4 Objective

Our main objective is to define needs to adapt the content presented by the M-learning application to the mobile device context used by learners, dictated by the design pattern. Another goal is understood the requirements better and influence the M-learning application development and its mobile devices come with theme templates, so we can do more easily develop M-learning design patterns that further improve M-learning applications in terms of adaptability, performance, reusability.

1.5 Contributions

The Proposition of mobile designs pattern has been realised before. In [2], Fang-Fang Chua offered a new version of the MVC pattern that can be used for separation between the application code and the presentation of content. We have contributed creating a new approach by using and adapting mobile design patterns for more take requirement of adaptation the content of M-learning application to the context of the mobile device used by learners. We attempted to clarify the effect of the mobile environment on design patterns to well comprehend how to create and reuse design patterns for mobile learning application development. We have reused some consistent design patterns to create mobile design patterns specific to mobile devices.

2 Literature review

Currently, almost every one has a mobile device [3]. In Oman, 99% of learners use a tablet or a smartphone. Authors in [4] described sex-based variances in attitudes towards mobile devices between learners: masculine learners used mobile devices more than feminine. At the same time features such as age, education and faculty were not important.

From the study of literature research papers, we have found some examples of works that have overcome the challenge of adaptation to the context of mobile device uses by M-learning application. Here is a brief explanation of the examples that we found.

2.1 Development of an M-learning application for early childhood education in emotional consciousness

In this article [5], the authors developed an application prototype founded on "Gamification" foundations intended in preschool students, in four vulnerable educational contexts in Popayan city (Colombia). Design Methods studied an iterative process in four phases - Analysis, Design, Testing, Delivery - and resulted in end-user validation of the app's visual design, as well as software registration. Validation assessments have concluded that the app being developed makes it easier for children to think, recognize and manage their own emotions.

2.2 An integrated context adaptive M-learning system

Author in this paper [6] presents a new M-learning system prototype providing learning services to learning users with reference to the context environment. A new learning context adaptation procedure is applied within the proposed prototype. This procedure utilizes a set of predefined profile, such as technical and learning profiles of users, used to understand the surrounding context, allowing the provision of adaptive and integrated learning services, fulfilling users' needs, and considering their preferences and capabilities.

2.3 Information quality characteristics for M-learning applications

This paper [7] presents a research study that investigates the potential to offer a content adapted a context of a mobile device by apply a quality analysis process for M-learning applications in agreement to a defined set of information quality characteristics in a attempt to growth the level of adaptation in the M-learning systems. These applications are studied and surveyed to decide if it encounters the proposed quality features or not. Authors focuse in this study, the most information quality features contain adaptability, reusability, testability, and security.

2.4 A work-based context-aware mobile learning system

Author in this thesis [8] propose the design, execution and assessment of a context-aware mobile system for work-based learning, termed WoBaLearn. A model implements a set of adaptation strategies for work-based learning and an adaptation engine to implement these methods is defined. These latters adapt learning supports reliant on professionals' just-in-time learning context. The author defined also an adaptation method which implements these methods to implement learning adaptations.

2.5 Solving technological, pedagogical, and psychological problems in mobile learning

The paper mentioned in [3] presents the various challenges and difficulties of the development of mobile devices in learning. Authors in this study, offer a specific framework designed to guide tutors in answering the problems that were identified in the work. The aim of this study is to examine the present state with mobile learning in universities of Russian. The main concentration in this work is on technological, pedagogical, and psychological aspects of the problem. Also, this paper offers references for the schools, tutors and learners to expand the state of mobile learning.

2.6 Development of an instructional design model for mobile blended learning in higher education

Authors in [9] used scenarios based on blended learning by merging several methods of learning and integrating a diversity of ways to get content via mobile technology. The aim of this work is to define a mobile blended learning design to guide the teacher or learner in pedagogical processes. By merging the concepts of mobile learning and blended learning, mobile blended learning design has been implemented. The mobile blended learning design has been created by the use of designing method and validation by experts. This instructional design has possibility to use in learning; then, it successfully growths the acceptance of mobile blended learning.

2.7 Summary

In my analysis of literature presented in this section, I observed that the adaptation concept traited by several methods. For exemple, in [5], the adaptation is attained by the constraction of models based an iterative process. The author in [6] propose a procedure of adaptation that used a set of predefined profiles. A set of information quality characteristics are defined an attempt to growth the level of adaptation in the M-learning systems [7]. In [3], Authors resolve the problems of adaptation in mobile learning by the specification of an integrated framework.

As a result of this analysis, I found that the concept of design pattern was not used to address the need for adaptation to the context of a mobile device, despite its importance.

In this paper, I take advantage of this lack to address the need for adaptation to the context of mobile devices used by learners in their learning process by proposing an approach based on a design pattern concept.

3 Presentation of the proposed approach

The analysis of the field of Mobile learning permitted us to distinguish important conditions to offer a content adapted to the mobile device context. At the same time, the proposed approach must be clearly identified and shared mobile learning environment situations, the information of the service to be represented and the learner profile, among the diverse system entities.

The phases followed a specification of design patterns used in my approach. These phases are presented as following:

- **Phase 1**: Collect information about the device used by learners during their learning process. This information includes the learner's profile acquired from questionnaires and tests.
- **Phase 2:** Specification of the set of rules of adaptation by using the information collected in previous step.
- **Phase 3:** Implementation of adaptation rules specified in previous step to provide adapted content to the context of a mobile device.
- **Phase 4:** The content must be decomposed into units. This decomposition must be produced automatically.
- **Phase 5:** Display of content decomposed to the learner.

We suggest, a based design patterns approach founded on suggestion rules interface system [10].

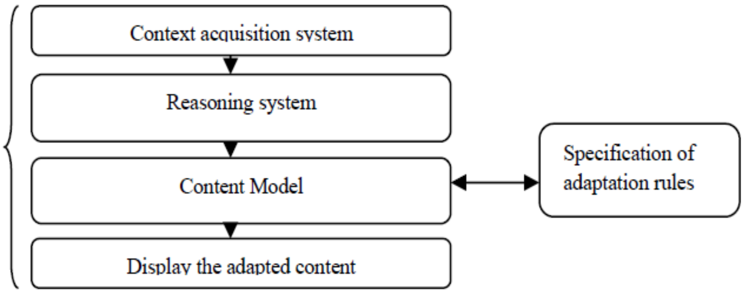

Fig. 1. Phases of the M-learning design patterns process

In the next, I will specify the role of each mobile design pattern used in our proposed approach.

3.1 Observer mobile design Pattern

A design pattern named *Observer* [1] provides a well solution to the collection of information problems. In M-learning applications, two sources of context's information can be defined: information linked to the profile of learner and information linked to the mobile device.

By observing a subject (observable), the pattern sends a notification to its observer each time a new context is detected and records this new information. In addition, we placed an observer on the mobile of the learner in order to acquire the contextual information. The sensors integrated are able to sense context changes like the level of noise, temperature, brightness, humidity, geographical position, etc. Platform-related variations such as screen size, the version of operating system, language: are also detected by these sensors. However, the observer is notified each time a change is detected, and he can execute the proper behavior while he receved all informations extracted.

The role of the Observer pattern is the observation of many subjects. So, this latter, detect any change in the context of use. Indeed, the Obervateur perception entity can detect events applied at the same time to many subjects. for this reason, we are reapplying the observer design model to observe learner-related changes.

In our case, the learner profile represents our second subject of observation, for this reason, the observer will also be applied to the terminal to build the learner profile. Figure 2 brings together the two use cases of the Observer pattern for identifying both the mobile learning context and data associated in the learner profile.

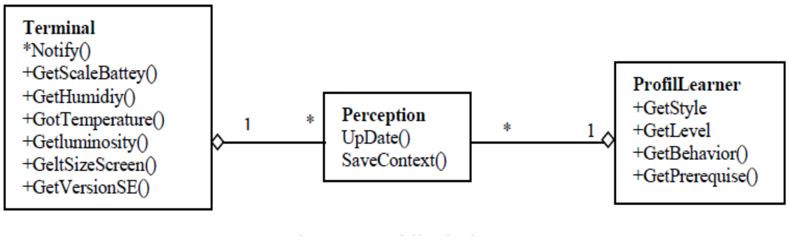

Fig. 2. Observer mobile design Pattern

3.2 Adaptation mobile design pattern

When observer pattern detect change in mobile device context, he save this new context, then he transmits extracted informations to engine rules for starting the reasoning process. The reasoning is achieved by business rules to define mobile learning conten to be showen to learner. So, the observer pattern will play the role of an intermediate among the entities forming the adaptation process.

We used the *Specification* design pattern presented in [1] to solve this problem. “It represents an effectively and reusable solution for the management of business rules and for the treatment of complex problems”. We are named this pattern as *Adaptation Pattern* which offer a context observation and specification of captured data. Figure 3 shows step of context identification seen in the preceding section (Observer pattern) and the step of reasoning achieved by the Specification pattern.

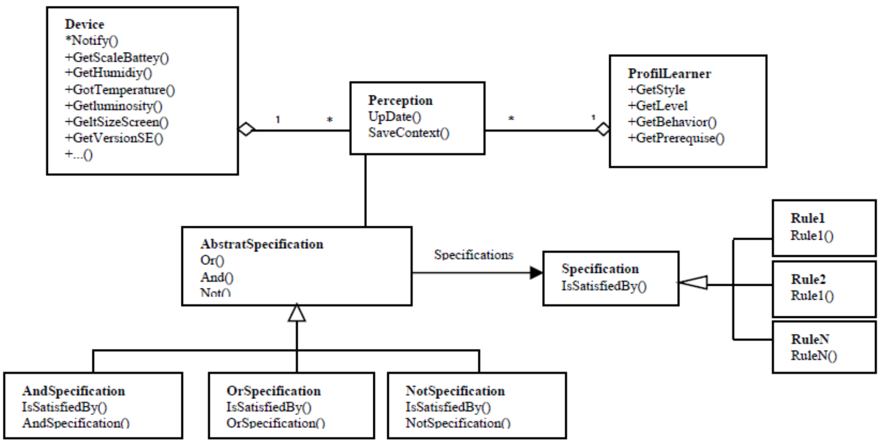

Fig. 3. Adaptation mobile design pattern

The Perception object saves the data once notified by the presence of a variation and diffuses it to the *Abstract Specification* object. The latter merge the boolean expressions "OR, AND and NOT" applied between the different predefined rules pre-arabled by the designer in the form "If (condition) then (conclusion)". A set of explicit statements will be expressed by these rules to describe the way in which they are applied by comparing its facts (data). All rules with a valid condition will be retained. This makes it possible to return only the data creating content to be displayed.

Our approach supports so far, the achievement of the context by using the Observer pattern and the specification of the adaptation rules depending on the context of the mobile device used by the learner and its profile. In the following section, we'll present the content composition part to be displayed.

3.3 Content mobile design pattern

Mobile learning uses a content model that holds diverse learning concepts. The same content of each has several views. The learning concept is showing to the learner according to their profile [11] and to the mobile device context used.

Two patterns: Specification and Observe are indispensable to build the elements of an appropriate content. Nevertheless, they are substandard to gratify all concepts, since they do not permit to present this concept to the learner.

The Builder design pattern [1] inclines to produce the composite objects element by element. It agrees to construct several versions or different representations of such a concept, using the similar code. In our work, this pattern has been used for the production of adapted mobile learning content.

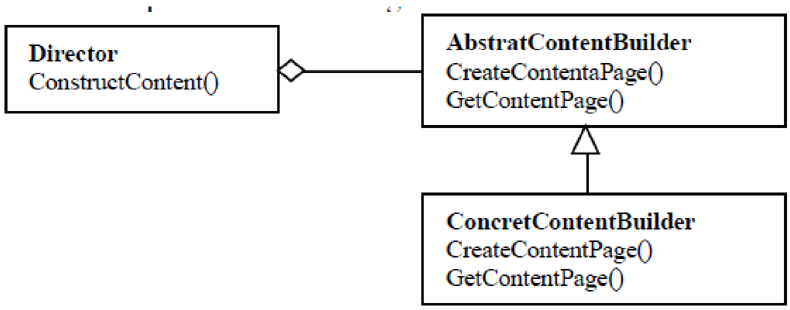

Fig. 4. Building Content mobile design pattern

As an example, a learner who has a visual learning style (depending on Fleming's model [12], the proper presentation for his style should include images and videos. But, if the sensors detect that the battery level of the mobile device is low, the proper presentation to the context of the device should not comprise videos, as they consume high percentage of energie. For this reason, the composition of mobile learning content exposed for the learner must go through two phases.

Figure 5 present the combination of the Builder pattern enable to produce mobile learning content with the Composite pattern enable to compose diverse content forms.

Director object permits the build of content using the Editor design method. This technique is stated by the business rule execution process quantified by the Specification template. The *ConcretContentBuilder* object constructs and accumulates several elements of content views. Content can be one item or a grouping of diverse kinds of items. For example, a description of such a content element may be textual form, or may be textual form with clarifying images. In most cases, four classes of learning content are recognized: Image, Text, Audio and Video. In our work, the composite design pattern [1] was used to present mobile learning content with their diverse forms.

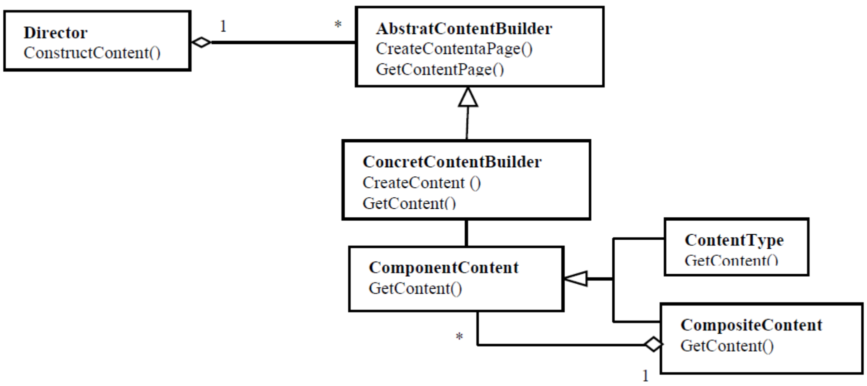

Fig. 5. The Builder-Composite mobile design pattern

The interface of the input elements in the mobile learning content composition are declared by the CompenentContent entity. The latter implements the default behavior of this interface. The CompenentContent entity is also used to define an interface for accessing and managing ContentType components.

The behavior of content composed of several types has been defined by the CompositeContent entity. The latter allows you to store components and implement the operations necessary to link different types of content. Thus, the CompositeContent consists of several other components, therefore, it also plays the role of a container.

The content elements are handled by the ConcretContentBuilder using the interface. Several types of presentations can be built by the ConcretContentBuilder by associating these content elements.

The Figure 6 illustrate our mobile design pattern proposed in our approach. We have named it "*M-learning design pattern*". It permits the identification of context, reasoning and construction of M-learning view to be showed to the learner.

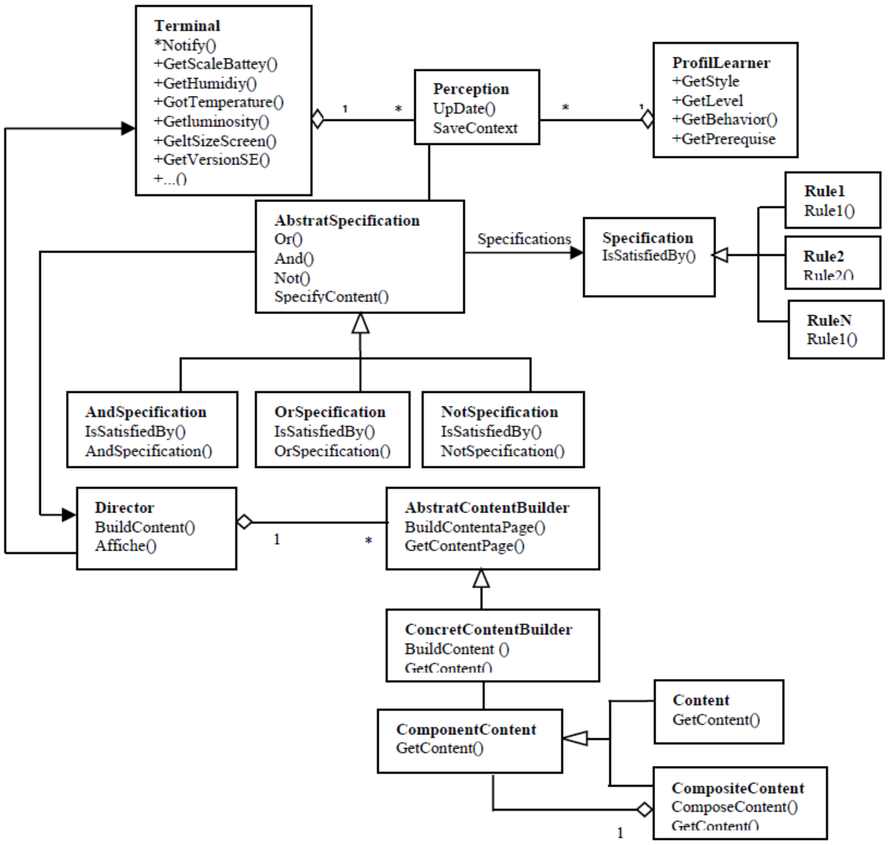

Fig. 6. Mobile learning design pattern

4 Implementation of the proposed approach

The adaptation of mobile learning systems requires a good approach for the acquisition of context, reasoning, the construction of learning content to be represented and the management of adaptation to each change of context.

The based design pattern and logic rules approach proposed covers these varied functional requirements. In this section, an implementation of a case study from our lives was carried out.

4.1 Case study

We will consider the following case study to illustrate our approach: A learner decides to follow a course via their tablet. The document supporting the course is composed of audio-video history of computer science, a text written in French, and an image relating to the field. Course content should adapt to the learner's learning style, preferences, and tablet capabilities. The learner chooses his preferences first. These represent contextual information such as: preferred and restricted language on video content, tablet capabilities such as location, ambient light, noise, etc.

Subsequently, the learner completed the questionnaire form "Swassing-Barbe Perceptual Modality Instrument". This quiz identifies the learner's learning style among Fleming's three learning styles: visual, auditory and kinesthetic. At the end, he sends his request. At this point, the application must adapt the content and the interface according to the preferences chosen and the resources of the terminal such as screen size, language, text orientation, etc. The application must therefore continue to manage adaptation to cope with the changing context of use.

4.2 Acquisition of mobile device context

The Observer design pattern makes it possible to detect any changes related to the environment or the learner platform through the sensors included in the device. In our case study, we limited the context elements to the following variables: noise, brightness, and battery level. These contextual elements are modeled using the key-value model given its simplicity in terms of its implementation. To do this, we relied on a data structure by associative table, as represented by Table 1. The values of the context elements come from different hardware and software sources.

Table 1. Context representation structure according to the key-value model

Key	Context type	Definition field	Source
Noise rate	Physical	Value >=0	Sensor
Brightness rate	Physical	Value >=0	Device
Battery level	Computational	Value $\in [0,1]$	Device

4.3 Reasoning

When contextual changes are detected, the *Perception* entity of the *Observer* pattern is notified of this variation. At this moment, the *Perception* retrieves its information and transmits it to the *Specification* pattern witch, first begin by the estimation of the learner style using an encoding grid, the system calculates the scores obtained for each of the possibilities a, b and c for each question. The encoding grid does the following:

- If the learner has a larger number of a, the dominant style is visual.
- If the learner has a larger number of b, the dominant style is auditory.
- If the learner has a larger number of c, the dominant style is kinesthetic.

Then the *Specification* pattern is responsible for qualifying the quantitative values of the elements of the context so that they are used more efficiently during the process of inference of adaptation actions, as illustrated by Table 2.

Table 2. Qualification of quantitative values of contextual elements

Key	Quantitative value	Qualitative value
Noise rate	< 200	Calm
	[200, 300]	Medium
	>300	Noisy
Brightness rate	< 200	Penombra
	[200, 350]	Bright
	>350	Very Bright
Battery level	< 30	Low
	[30, 70]	Medium
	>70	Full

Finally, the Specification pattern takes care of training the elements of course to be represented. This step is carried out using the rules defined in Table 3.

Table 3. Rules of inference for adaptation actions

ID	Conditions	Action
R1	IF (Style=visual) and (Brightness=penombra) ou (Brightness= bright)	BuildContent (text, Image)
R2	IF (Style=visual) and (Brightness = Very Bright)	BuildContent (Audio, Image)
R3	IF (Style=auditory) and (Noise=calm or medium)	BuildContent (text, audio)
R4	IF (Style=auditory) and (Noise=Noisy)	BuildContent (text, Image)
R5	IF (Style=auditory) and (Brightness = Very bright) and (noise=calm or medium)	BuildContent (Audio, Image)
R6	IF (Style=Kinesthetic) and (Battery=medium ou full) and (Noise=calm or medium)	BuildContent (texte, video)
R7	IF (Style=Kinesthetic) and (Battery=low) and (Noise=Noisy)	BuildContent (text, image)

At the end of this process, a data set forming the course to be represented is ready to be sent to the Builder pattern to build the adapted content of the course.

4.4 Course composition

The *Builder* pattern of our model takes care of building the course. Already possessing the data forming the course to be represented, he delegates the task of interface composition to the *Composite* pattern. The SCRDR "*Single-Conclusion Ripple-Down Rules*" expert system [13] is built while the application is running. It begins with an empty knowledge base system that will be built over time as the context of use evolves. The subject matter expert therefore adds rules, conditions and conclusions to satisfy course construction to its condition of use.

The condition part of the rule. For this part of the rule, we started by creating three models specific to our example: The first model includes learner tasks such as: open application, complete questionnaire (the learning style estimation questionnaire used in our example contains 30 questions, three possible answers for each question), display style (Once the learner has filled in the learning style estimation form and validated his answers, he can know his estimated learning style) and start the course.

```
<taskModel> <!--Definition of system tasks-->
    <task id= "task1" name= "Open application">
    <task id= "task1.1" name= "Answer questionnaire">
    <task id= "task1.1.1" name= "Set Choix 1">
    <task id= "task1.1.2" name= "Set Choix 2">
    …
    <task id= "task1.1.30" name= "Set Choix 30">
 </task>
<task id= "task1.2" name= "Show style">
  <task id= "task1.2" name= "Start cours">
</task>
</taskmodel>
```

The second model is specific to context information, namely noise, light, battery level and style type. The adapted course will be exposed according to this information.

```
<ContextInformationModel>  <!--Definition  of  Planned
Information-->
    <context id= "style"></context>
    <context id= "noise"></context>
    <context id= "battery"></context>
    <context id= "light"></context>
</ contextInformationModel>
```

The last model is related to the platform. It indicates which mobile is used per learner. Therefore, the screen size will be easily detected and the interface will be specific to the phone's operating system.

```
<ContextModel><!--Setting Preferences-->
     <çontext id= "Mobile" name= "HUAWEI Gm1"></context>
     <context id= "SE" name= "Android 7" ></context>
     <context id= "Language">
       <context id "Language 1" name = "French">
       <context id "Language 2" name = "English">
</context>,
     <context id= "Orientation Text">
     <context id" Orientation Text 1" name = "Paysage">
     <context id " Orientation Text 2" name = "Portrait">
</context>
</ contextModel>
```

These three elements are stored in a knowledge base and they will be enriched according to our needs in order to satisfy the creation of courses depending on the variation of context.

The action part. This part specifies a description of the content type forming course to be represented. From the rules used in our case study, the course content is a couple of the following elements: text, image, (audio and video. So, the course can be one of the following pairs: (Text, Image), (Audio, Image), (Text, Audio), (Text, Video), (Image, video), (audio, video). As an example, we have created a specific interface for the description of a course which consists of a text and an image.

```
  Main layout DisplayCourse {
    Item item1 : TextContainer { top;}
    Item item2 : ImageContainer {below item1}n
    Align top;
    Marginx = 0;
  }
  LayouttextContainer : {
    Item textView{ Backgroung = x00ffffff, font-size=12;
font-face-TimeNewRoman ;
    }
  }
  LayoutimageContainer : {
    Item   imageView{width   =   "largeurscreen";height   =
"hauteurscreen/2"; belowmost     textView ;}
  }
```

The main layout"*DisplayCoures*" contains a text (item1) at the top and an image (item2) which is positioned just below the text. The latter is defined by a *layoutImageContainer* which includes an element of type *ImageView* whose width is equal to the width of the screen and its height is equal to the height of the screen divided by 2.

4.5 Illustrative scenario

In this section, we present an illustrative scenario for which the process of adaptation will be triggered by considering some assumptions. Miss Sarra is a computer science student at an Algerian university; As she moves, Sarra wishes retrieve a document related to the 3D printing machine. The multimedia content must be adapted to sarra's preferences in terms of: preferred language, capabilities of her Smartphone such as battery level, ambient light, noise, etc. In the proposed scenarios, we used a typical document that is a web page containing the components of course consulted by Sarra.

First use case. Sarra is in an auditorium and uses her smartphone to access the course. The battery level of her smartphone indicates that he has reached the level of 24%. The contextual constraints deduced by the adaptation system are as follows: kinesthetic style, low battery and noisy environment. Therefore, rule R7 must be executed to provide a adapted document that conforms as much as possible to the current contextual constraints. The result of the adaptation process will be as shown in Figure 7 (left side).

Second use case. Sarra is in the university lab using her smartphone to access the course. The battery level of her smartphone indicates that he has reached the level of 78%. The contextual constraints deduced by the adaptation system are as follows: kinesthetic style, battery full and calm environment. Therefore, the rules *R6* must be executed to provide a suitable document which conforms as much as possible to the current contextual constraints. The result of the adaptation process will be as shown in Figure 7 (right side).

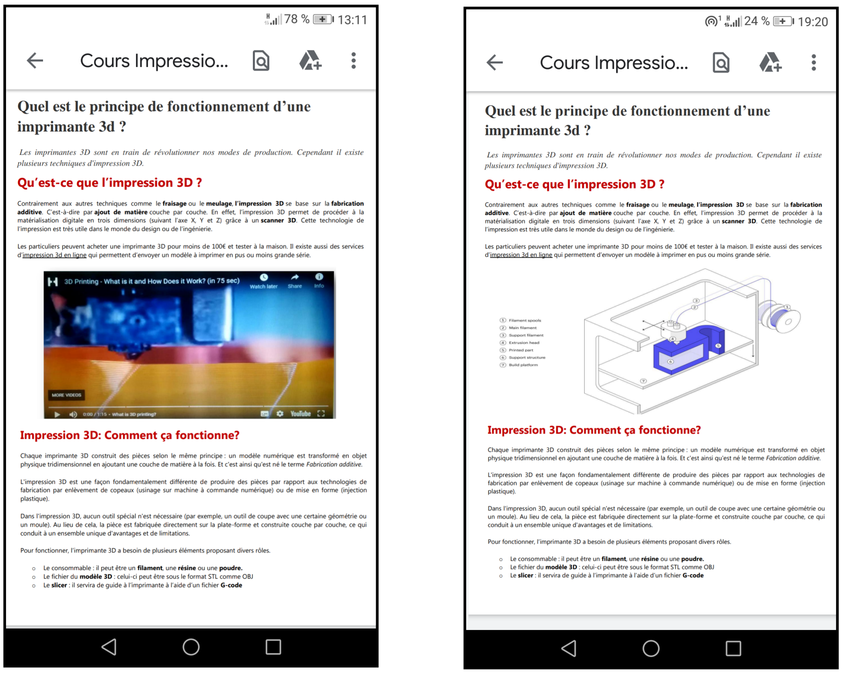

Fig. 7. Results of the first and the second scenario

Discussion. The above scenarios illustrate the importance of understanding context to infer users' current contextual constraints and thus perform actions Useful. The adaptation operation therefore makes it possible to offer a suitable document that complies as much as possible with the constraints of the target profile. By proceeding in this way, we ensure the continuity of the service (consultation of the document) even with inferior qualities. In addition, this prototype could have been extended by other elements of the context from different sources such as sensors (e.g., temperature), services (e.g., weather) and profile (e.g., agenda). Therefore, more inference rules and accommodation services could have been involved. Although these suggestions may lead to improvements in the quality of adapted documents, such situations may pose problems of consistency between the rules for inference of adaptation actions, which can have a negative impact on the quality of the adaptation process. As proof, it is enough to observe the second scenario, the rules R3 and R5, they can be executed in the same adaptation process and they give two types of course presentation. To remedy this problem, we can, for example, set priority levels for the rules or leave the choice to the learner to execute the rule that it seems appropriate.

5 Conclusion

While there are different methods to adapting learning content to the mobile device context, particularly for mobile systems, they still have some limits. Starting with this remark, we take these shortcomings to make them the subject of this study. We have focused our efforts on the challenges of these systems, such as taking into account a limited number of contexts and not having an adaptive process. Such forms of adaptation need: a) identifying any relevant contexts for learners and b) developing a model that supports adaptation of the learning content. To realize our objective of adaptation learning content to three contexts (i.e.: learner, platform, environment), we proposed a design pattern, based on a set of design patterns, which supports both gathering context from many sources and specifying inference rules. The appearance of this content is suggested by an expert rule-based knowledge acquisition system.

However, to implement our approach, we developed our design model by applying it to a real-life case study. We have also identified the different elements that make up our rules-based expert system. It is the latter that we propose to enrich in order to cover a wide range of learning contexts. While our approach takes into consideration a wide range of contexts when adapting learning content, it does not lack limitations. Among the latter, we can mention the non-support of several development platforms simultaneously. Finally, through this work, we hope to have interactive systems adaptable to different contexts while maintaining the reusability of our approach in the context of future issues.

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7 Author

Dr Hamza Lamia is a lecturer in computer science field working at University of Oum El Bouaghi, algeria. She obtained a Doctor of Science degree in 2019 at badji Mokhtar University of Annaba, Algeria. She obtained in July 2010 a magister degree in computer science, software engineering option, University of Oum el Bouaghi in Algeria. Her research interests include design pattern, Hypermedia systems, E-learning, and M-learning. The author can be reached through her official email address which is: hamza.lamia@univ-oeb.dz, Or lamia.hamza@yahoo.fr.

Article submitted 2022-11-19. Resubmitted 2023-01-18. Final acceptance 2023-01-20. Final version published as submitted by the author.