EVALUATION FRAMEWORK FOR DEPENDABLE MOBILE LEARNING SCENARIOS

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ABSTRACT

The goal of the dependability analysis is to predict inconsistencies and to reveal ambiguities and incompleteness in the designed learning scenario. Evaluation, in traditional learning design, is generally planned after the execution of the scenario. In mobile learning, this stage becomes too difficult and expensive to apply due to the complexity and heterogeneity of mobile infrastructure with contextual constraints. In other word, the test of the dependability has to be alone at early stage. To achieve our goal, evaluating the dependability of the learning scenario, the evaluation model is constructed from the analysis of literature by exploring different aspects of dependability. We propose to apply formal specification and verification in order to evaluate the functional dependability of the mobile learning environment. A specification is the description (usually by means of a temporal logic formulas) of the property (or temporal behaviour) to be fulfilled by the environment under consideration. Verification consists on (exhaustively) proving that the learning environment is correct.

KEYWORDS

Mobile learning, evaluation, formal specification and verification, learning scenario

1. INTRODUCTION

Dependability is an important pre-requisite for mobile learning (Magal-Royo, T. et al, 2007) and should be evaluated sufficiently and at early stage to respond user's requirement. In fact, the learning environment had to operate as learners and designers expect and that it will not fail in normal use (Lê, Q. and Lê, T, 2007).

Many researchers have defined the dependability in slightly different way. Dependability is an orthogonal issue that depends on QoS. We consider its original meaning as defined in (Laprie, J.-C, 1985), (Avizienis, A. et al. 2004) : "*Dependability is the quality of the delivered such that reliance can justifiably be placed on this service*". It could be typically divided into a number of aspects namely (Avizienis, A. et al. 2004): (functional) correctness, safety, security, reliability, availability, transparency and traceability. Each dimension includes analysis techniques, assessment methods and measures. Mobile learning environments come with requirements from all aspects of dependability. The reason for this lies in the nature of these mobile scenarios itself. Typically these environments are very tightly connected with specific users.

Dependability evaluation is an important activity as well as evaluation of the executed learning scenario. Post-evaluation techniques and approaches take much time and cost, and an early preventive evaluation could be one of the key factors to cost effective mobile learning development.

The basic question is: *How to evaluate the learning functionalities in their context of use at early stage in order to ensure the dependability of the conceived scenario*?

To answer to this question, we first summarize our definitions. We define learning scenario as technological environment consisting of one or more activities, correlated together offering a complete scenario of information and communication services required for supporting learning. A mobile learning can be defined as "*… any service or facility that supplies a learner with general electronic information and educational content that aids in acquisition of knowledge regardless location and time…*" (Lehner, F. and Nosekabel, H. 2002.).

This paper proposes an early preventive evaluation framework: ReStart-Me (**R**e-engineering **e**ducational **S**cenario based on **t**imed **a**utomata and t**r**acks **t**reatment for **M**alleable learning **e**nvironment) that intends to reduce the time and cost through using test cases as a means of the evaluation. Test cases are developed in the process of the leaning scenario design and used to test the target scenario. ReStart-Me checks formally inclusion relation between dependability requirements and test cases.

2. BACKGROUND AND RELEATED WORKS

2.1 What can we evaluate in Mobile Learning Scenario?

As computers have become more rapid and powerful, educational software has flourished and there are numerous claims conceived by designers. Thus evaluation software is important so that teachers can make an appropriate choice of learning scenarios and which are suitable to the teaching and learning context.

According to (Elissavet, G. and Economides, A. A. 2003) we can evaluate these following dimensions in a learning scenario: content, technical support, learning process (see figure 1). Each dimension includes a number of sub categories and criteria that could be considered in the evaluation process. All these aspects are equally important, as the learning activity has to be simultaneously pedagogically and technically sound.

However, we propose that the learning activity's context should also be considered for evaluation. The context is a set of evolutive elements appropriate to the interaction between learner and learning application including the learner and the learning environment themselves. Figure 1 presents in a diagram the different aspects that we can combine and include in the evaluation framework.

Mobile learning could be evaluated from different viewpoints: The first one is a technical oriented perspective. The content suitable for m-learning needs to be available and adequate to the learning environment. The second one is pedagogical oriented perspective. It points out that m-learning develops new skills and approaches to ensure the pedagogical effectiveness. We consider that the context of mobile environment should be also considered in evaluation process. The features of activity's context are: location, network, user, time and device.

- **<u>The device dimension:</u>** we consider that it is important capabilities of user's device, especially hardware attributes, for mobile learning due to the fact they have a big impact on learning scenario execution.
- **<u>The network and connectivity dimension:</u>** nowadays mobile device might be connected to the "Net" via many technologies: GPRS, UMTS, WiFi, 3G-telecommunication, etc. Mobile devices often have periods of disconnection that had to be considered in evaluation of the dependability of the learning scenario. The connectivity quality depends on user's location and mobility.

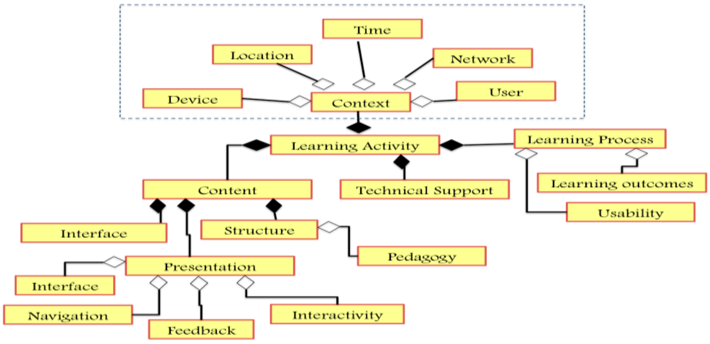

Figure 1. Different features that could be evaluate in the learning scenario

2.2 Evaluation of Mobile Learning Scenarios: Related Works and Issues

There have been several researches to develop methods to evaluate mobile learning scenario. The most widely used methods are:

- Heuristic evaluation method based on principals and many categorised dimensions (Nielsen, J. and Molich, R. 1990). A wide range of methods has been developed to systematically evaluate the quality of information technologies.
- Evaluation methods based on Simulations (Polson, L. C. et al. 1990) where some user problems are simulated in details, especially analysing each task from a cognitive point of view.
- Evaluation system based on tracks analysis requests both analytical and technical staff. The first group is responsible for defining scores for various features of the e learning scenario according to a specific set of evaluation coefficients. This team also specify the quality of the learning scenario. The technical staff develops the system or specify the evaluation framework to the mentioned scores (Zorrilla, M. and Álvarez, E. 2008) (Ben Sassi, M. and Laroussi, M. 2012).
- Teaching test methods are based on an appropriate testing program that is suitable to different goals and characteristics of the teaching style. These methods implement the pre-test, the post-test of the learning scenario, and other steps to test the knowledge of students and their skills and finally determine the effectiveness of teaching scenario (JIAa, Z. and Han, X. 2013).

As shown, there are several evaluation studies. However, these methods vary widely in their evaluation scope, outcomes and techniques. In fact, in the one hand, there are generic methods that, although useful in theory, are not very applicable in practice, since they do not take into account the situatedness of the courseware evaluation, determined by the context of the learning scenario. In the other hand, some of these methods described above have a very specific target (cognitive overview). Nevertheless, with the growth in the use of mobile technologies and the learning scenario database, an increasing number of teachers want to reuse their scenario in different contexts.

Instead of adding to the already large number of checklists for learning scenario evaluation, we are attempting, in the following section, to address contextual evaluation based on formal modeling and verification of educational scenario. Next, the evaluation framework is discussed.

3. RESTART-ME: A FORMAL EVALUATION FRAMEWORK FOR M-LEARNING

3.1 Restart-Me Challenges

In order to fill the gap between learning scenarios evaluation methods and mobile learning scenarios, we present in this paper, a formal method to evaluate scenarios at an early stage: ReStart-Me (Re-engineering educational Scenario based on timed automata and tracks treatment for Malleable learning environment). This formal evaluation is based on automata theory and formal verification and aims to:

- Avoid costly and time-consuming scenarios implementation or deployment
- Simulate scenario execution on real time in order to check properties and to detect errors (such as deadlocks and liveness) and then to regulate scenario with timing constraints.

The evaluation framework is based on different kind of context: Actors, Location, Device, Network and connectivity. These elements are motivated by an empirical analysis of different definitions of learning context. In fact, these elements represent core features of any educational scenario supporting any learning approaches such as hybrid learning, mobile learning, ubiquitous learning, pervasive learning,... Consequently, they represent interesting evaluation criteria in order to capture at early stage inconsistencies and design weakness.

3.2 Conceptual Framework

Figure 2 overviews the proposed software dependability evaluation framework for mobile learning. ReStart-Me intends to reduce the cost of learning environment quality evaluation through using test cases. It uses formal checking techniques to ascertain inclusion relation between dependability requirements and test cases. Dependability requirements and test cases are modeled into timed automata. Then, they are transformed into temporal logical properties to formal checking methods. If the formal checking produces TRUE then we can conclude that the dependability properties are well implemented into the learning environment. On the other hand, in case of FALSE, we generate an errors report and recommendations to assist designers to ensure learning scenario quality.

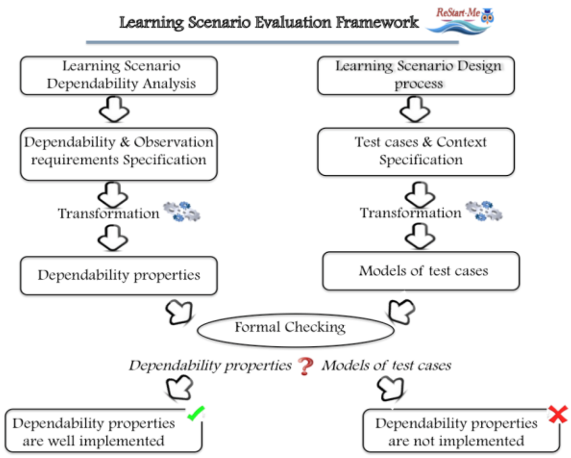

Figure 2. Dependability Evaluation Framework for Learning Scenario.

The evaluation process contains essentially these three steps (see Figure 2) inspired from (Coronato, A. and De Pietro, G. 2010):

- **Pre Step 0: Behavioural Modelling:** this phase provides informal descriptions of both the learning environment and the correctness properties to be checked. Pedagogues and designers have to participate in this phase.
- **Step 1: Formal Modeling of Educational Scenario:** In this step, conceptual designers identify the entities to be considered. Designers have to successively refine it and decide which the final actors to be modelled are. The content of each process is created and redefined by modelling the dynamic behaviour. Then, we extend the obtained automaton with global and local clocks. We also define contextual constraints and correlation between different activities. By creating a formal specification of the learning scenario, the designers are forced to make and to define a detailed scenario analysis at early stage before its deployment into the learning system.
- **Step 2: Tracks Simulation:** Through simulation, we can observe all possible interactions between automata corresponding to different entities involved in the learning scenario. This step generates simulated tracks that facilitate errors detection. A simulation is equivalent to an execution of the designed learning scenario. It gives some insight on how the model created behaves.
- **Step 3: Properties verification**: with formal verification, we check the correctness of the designed learning scenario. This process aims to build a remedial scenario and to help designer in the reengineering process by providing Errors and warning reports.

ReStart-Me can be applied with the help of different developing methods and tools. To exemplify this, we have selected a tool that is well known, efficient and provide us with most of what we need. The selected tool is a model checker that has a modelling language, plus simulation and formal verification capabilities. We think that our choice is well founded but is not essential. To illustrate the application of ReStart-Me, we will use UPPAAL model checker (Bengtsson, J. et al. 1996).

4. EXPERIMENT AND RESULTS

The objective of this study reported in this section is twofold: (i) to check practicality of the proposed framework when building an actual mobile scenario (ii) and to evaluate qualitatively the benefits of such methodology. A team of researchers composed mainly by of five Designers has prepared a textual description of the malleable learning scenario.

These meetings have produced a scenario design document that describes the sequencing of different activities and rules of the malleable learning scenario. To summarize, the learning scenario can be described as follows:

A high school decides to raise awareness of pupils on the effects of pollution on the environment by organizing a trial allowing the follow-up of the pupil's educational curriculum in the field of "Education about the environment". This trial enables pupils to learn through factual cases and to experiment various scenarios using pervasive and mobile technologies.

The physical setting of this trial, where activities take place, is an ecological zone near by an industrial area.

In order to boost intra-group competition, students were divided in three groups under the supervision of their coach and each group consisted of six pupils. Additionally, each group was divided in two subgroups of three students. The ultimate goal behind this clustering is to reinforce teamwork and collaboration within the individual subgroups and to make it a collaborative and challenging game that takes place in different locations.

The outdoor subgroup is equipped with a smart phone with a wireless connection. At the beginning of the first stage, a localization sensor localizes the out door's subgroup and a notification is sent to ask students to identify and take a photo of the QR-code stuck to a tree. Instantly, a text adapted to the pupils' level and pictures that visualize and describe the activities to accomplish in the current stage is displayed on the screen of the smart phone.

In the first stage, the outdoor subgroup can take a photo of a plant and search for a plant related groups and then share the photo and ask for help in identifying it. After a pre-defined time, the subgroup will receive a stage-adapted quiz via automatic text message. Pupils need to write an answer using their smartphone and submit it. If the answer submitted by the group is not correct, the system sends an alert to the coach informing him/her that pupils need some support. The coach should send to them some hints.

In order to improve the coaching task, tutor decides that after three wrong attempts, the pupil is guided to start learning session by using his mobile device. The e-learning client allow the student to directly mash up widgets to create lesson structure and add powerful online test widgets, communication widget (chat, forum and personal messages), content scheduling widgets, communication tracking, announcements, content flows, cooperative content building widgets.

The student could drag from the widget repository and drops into the elearning client UI all the widgets needed for providing video, audio and other multimedia content. The session of learning take 30 minutes with GPRS connection and 40 minutes with EDGE connection.

Else, if the answer is correct the indoor subgroups will receive the list of activities of the second stage and will get joined by their corresponding outdoor subgroups that will hand over the picked plant samples.

At the end, indoor and outdoor subgroups of each of the three groups should collaborate in drawing their own conclusions using the collaborative tool Google Docs and then present the outcome of their study about effects of pollution on environment.

Table 1. Context Information (Network connection quality)

	Zone 1	Zone 2
Type of network	**EDGE**	GPRS

4.1 Modelisation and Evaluation

Figures 3 and 4 provide an overview of different automata modeled for the planned learning activities (outdoor activities, quiz, and lesson) and corresponding to student. We define a global variable "clock" named Time that gives idea about the duration of each activity. The timing constraints associated with locations are invariants. It gives a bound on how long these locations can be active. We also define other global variable Power to calculate the energy of battery of the smartphone.

In order to facilitate the learning scenario analysis, we model each activity separately. The idea is to define templates for activities that are instantiated to have a simulation of the whole scenario. The motivation for the use of templates is that the understanding, the share and the reuse of different components of the learning scenario become easier.

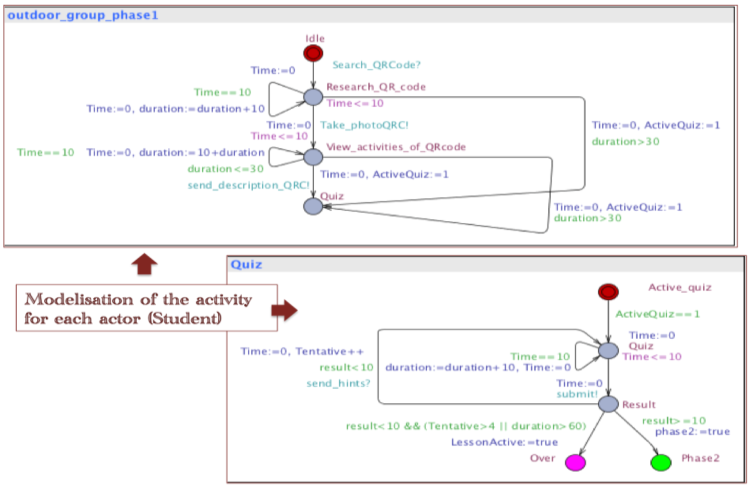

Figure 3. The automata model of different activities for one actor (Student)

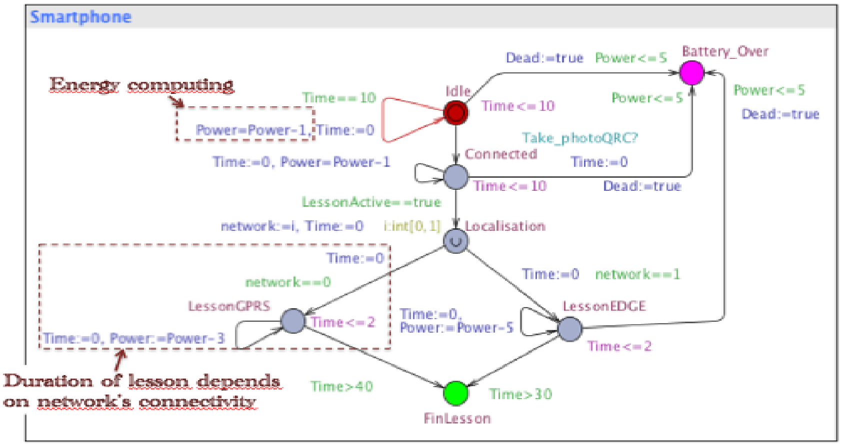

Figure 4. The automaton model of the smart phone

The whole scenario is modelled as a parallel composition of timed automata. An automaton may perform a transition separately or synchronise with another automaton (channel synchronisation) or it can be activated after a period of time through flags.

Based on automata presented above, tracks simulations are generated visualizing all possible interactions between different actors. A screen dump of the simulation of the designed educational scenario is below (see figure 5).

In order to help designers to improve their educational scenario and to obtain better outcomes, through the generated simulations, we try to localize design errors, to answer and to verify the following questions:

- **Does the description of the learning scenario clearly define time constraints for each activity and the whole scenario?**
- **Is there any situation of deadlocks, liveness or starvation?**

A possible situation of deadlock is detected within tracks simulation of the whole scenario; In fact, students could have a period of inactivity especially when they begin their lesson in the first zone (EDGE) where the network connectivity is lower and smartphone' energy is limited. To check this property, we are based on reachability property that is considered as the simplest form of properties. They ask whether a given state formula, possibly can be satisfied by any reachable state. Another way of stating this is: Does there exist a path starting at the initial state, such that "the battery state" is eventually over along that path?

We traduce this property in temporal logic formula: "*E<>Smartphone.Battery_Over*" and this property is verified as shows figure 6. Then, we conclude that dependability is not assured and we had to adapt mobile application to the learning environment context (if the student is located in Zone 1, he had to reduce the energy consumption by loading the necessary widgets).

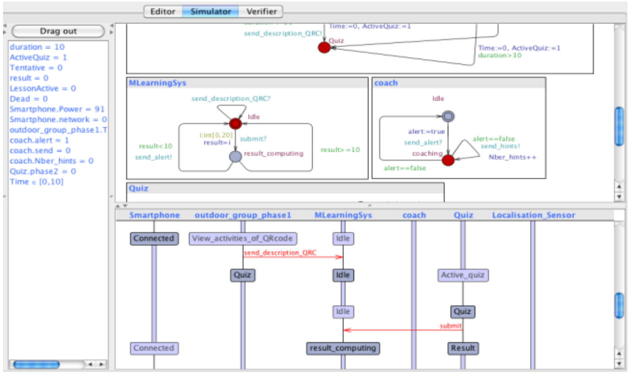

Figure 5. Simulation of the modeled Learning scenario

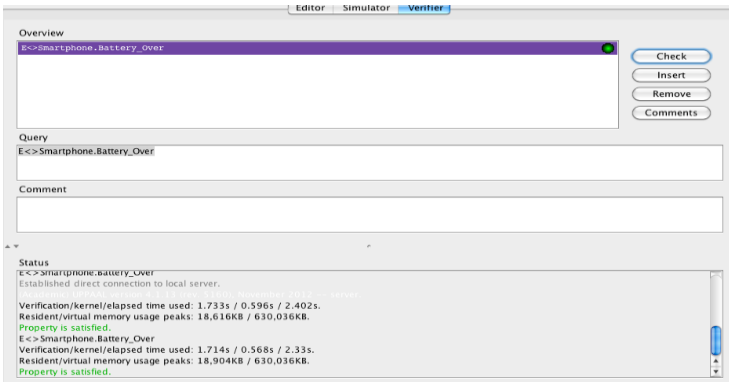

Figure 6. Checking the reachability of the battery state

4.2 Result

The final evaluation was conducted using interviews with five pedagogical designers. During the interview, the engineers have addressed several points about there experiences with the presented methodology. Hereafter a summary of the main points that have been discussed:

- Fours engineers of five have found the methodology very useful in identifying the inconsistencies functional aspects of the learning scenario. In fact the culture of classical learning scenario evaluation does not highlight the importance of these functional aspects (like time, context of learning, ...). In the one hand, thanks to the formal modelisation, we can simulate and check all possible execution exhaustively. In the other hand, it allows us to redefine the conceived learning scenario in more details deeply at early stage in order to avoid the problems highlighted by the evaluation (or on the contrary, to rethink the first design).
- Two engineers have already some experience in developing large learning scenario. So they were aware of the cost of their implementation and revision. Consequently, they pointed out that the early evaluation stage performed before implementation and deployment has helped to revise some fundamental decision without having to conduct costly implementation. In fact, the contextual and formal evaluation shows us if the resulting evaluation is exactly what we expect from the modelisation of learning scenario (and from the learner) before the implementation stage. It may happen, for example, that we want to create a correctly and general design for a complex scenario but the result of the formal evaluation shows that we lack in contextual constraints definition and specification.

- Three engineers of five have pointed out that the formal modeling and verification is not so easy to build. Indeed, this formalism is not very well known by all conceptual designers. For this reason, we are developing a formal modelisation assistant tool to help no-skilled designers to evaluate the conceived learning scenario.

5. CONCLUSION

In this paper, we presented different dimensions that could be evaluated in learning scenario. We proposed a formal framework evaluation to support a contextual evaluation in dependable learning environment. This framework based on formal modelisation and verification allows to designers to simulate the conceived learning scenario with contextual constraints.

Complex content management is employed in m-learning, when there is an interaction between teachers and students. The limit is established by the available technology. It is still a determinant factor in such technologies, the transmission cost and speed, which affects the communication logistic between teacher and student and has a direct repercussion on the learning type. For this reason, we have attempted to demonstrate the benefits of the proposed approach by presenting a realistic case study. We think that this formal methodology of evaluation provides useful information for the re-use and the reengineering of learning materials. In the one hand, it can solve many difficulties in getting proper information about the students and their behaviour (ethical problems, track s' collect,...).

In the other hand, the use of a rigorous formalism to describe a model of deployment allows a better and more precise understanding of the planned scenario. It provides the designer with an analytical model that helps him to detect errors and learner's difficulties through test case generation and deductive verification. Finally, it creates an environment that simulates an external reality and learner's behaviour.

For going farther this first result, we are currently working on two directions: Firstly, we will attempt to deepen our proposal and to apply formal verification relying on temporal logical formulas and model checking engine. Secondly, in order to assist the designer in expressing these properties, we are developing a tool that helps him/her to draw this business requirement and to generate error report automatically.

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