An adaptive environment based on Moodle with treating of quality of context

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Abstract: Ubiquitous learning (U-Learning) environments collect context information relative to user's preferences and needs, but this information is typically very volatile. On this basis, the Quality of the Context aims at treating this information with the application of the quality parameters. This paper presents a ubiquitous virtual environment, in which three modules (U-SEA, SEDECA and QoC) were developed and integrated with Moodle, and describes the use of a Bootstrap theme to automatically adapt the interface on mobile devices. The results about the integrated modules showed that the UVLE^{QoC} environment operated satisfactorily, based on the assessments made by the group of users who tested the modules and their operation.

Keywords: U-learning; QoC; quality of context; context; Moodle; mobile adaptation.

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1 Introduction

The introduction of information and communication technology (ICT) into the educational field added new learning paradigms (such as E-Learning) based on a non-face-to-face teaching model underpinned by the use of technology. E-learning can be conceptualised

as all forms of electronically supported or mediated learning and teaching Moore et al. (2011). Virtual learning environments (VLEs) (e.g., Moodle) are used to support the adoption of this model in educational institutions, as they allow the creation and development of educational projects and activities.

The evolution of technology resources over the years has fostered the development and adaptation of new methods and applications relative to the E-Learning model, allowing the introduction of new branches in this medium, such as the design of a new model called ubiquitous learning (U-Learning). Ubiquitous computing is an example of the emerging area, in the definition proposed by Weiser (1991) that says that the Ubiquitous Computing allows the people and the environment, with the combination of various computing technologies, to swap information and services at anytime and anywhere.

The use of this technology in many different areas aimed at facilitating user interaction with the computational applications, as it can be seen in the area of education, with the introduction of U-Learning. According to Yahya et al. (2010), U-Learning can be described as a learning paradigm that uses ubiquitous computing environments and allows learning to occur 'anywhere and anytime'. Thus, students have at their disposal in the most propitious time, content suitable for their learning, taking into account the location and context in which it is inserted.

One of the key aspects that are directly linked to ubiquitous computing is context information, which, according to Dey (2001) can be defined as any information that can be used to characterise the situation of entities that are considered relevant to the interaction between a user and an application. The context can be constructed from different types of information such as speed of the network connection, location, user preferences, etc.

Examples of computer applications that use context information are the VLEs, which have been adapted to suit the needs of users, as seen in the work of Piovesan et al. (2012) and Filho and Agoulmine (2010). However, the context used in these environments are subject to imperfections as explained in Piovesan et al. (2012) and Santos (2006), wherein the context information have a high probability of defect or inconsistency caused by inaccuracies in the acquisition and maintenance of context.

In accordance with Manzoor et al. (2008), context-awareness systems are not exerting enough effort to use information's related to the quality of context (QoC) in order to enhance their performance. Thus, their interaction with the environment to carry out the activities becomes more costly and may result in user rejection regarding the use of the environment, due to their dissatisfaction and difficulty of use. The Subarea QoC aims to address these issues, which, according to Krause and Hochstatter (2005), can be defined as any data that describe the quality of information that is used as context. Thus, the objective of QoC is to contribute for validating the final outcome presented to users and meet their needs, providing a context that is appropriate for their situation.

Thus, this paper aims to demonstrate the feasibility of adapting an U-Learning environment to suit the handling rules of QoC information and provide an appropriate context to the preferences and needs of the user. A prototype was presented with the development of three modules and their integration into the Moodle environment, which was used as basis for the development of this work. Furthermore, a theme called Bootstrap was integrated into Moodle to provide the automatic adjustment of the interface for use of the environment in mobile devices.

In the module titled 'QoC', parameters and metrics for QoC are applied to the information collected from the environment, so that there is greater assurance that the framework formulated in the environment was suited to user's preferences and needs. SEDECA and U-SEA modules collect context information in the environment; such information is formed by user's cognitive profile and their connection speed, respectively. The adaptations to the environment are carried out using the adaptive hypermedia (AH) technique.

The structure of this paper is organised in the following way: in Section 2 are presented related jobs involving the area of QoC and its relationship with the developed research; in Section 3 is performed a theoretical about the main topics involved in this work; in Section 4 is presented the methodology used in this study; Section 5 explores the development of adaptive environment; Section 6 presents the initial tests performed for the evaluation of the environment; and, finally, Section 7 contains the conclusions and future work in this research.

2 Related work

In order to develop this work, a systematic analysis was conducted involving researches related to the area of QoC in order to use the expertise of other studies for formulating this proposal. Are described below some of the relevant studies reviewed:

Yasar et al. (2011) aimed to provide efficient communications for the established network; for this proposal, the communication was divided into two phases: the first is focused exclusively on QoC, while the second aims to determine the reputation of the nodes involved in the communication. Their contributions are the definitions of information acceptable limits, in order to ensure a minimum quality, eliminating those that are not within these standards.

The work of Manzoor et al. (2008) conducts an assessment of the QoC parameters, in which they are quantified to be presented in an appropriate way and to be used in pervasive environments. A model of QoC for supporting in situations of disaster was created and is being presented in this paper, in which the following parameters were evaluated and structured: timeliness of information, reliability, completeness and significance. The results were prepared for measuring the formulas and the attributes involved, as well as the development of the algorithm for these four parameters.

Zheng et al. (2011) presented a context-sensitive framework that supports management of QoC in several layers, performing the elimination of duplicated context and the removal of the inconsistent. The framework allows one to evaluate the context in its raw form, discarding those that are duplicates or inconsistent to provide context information with an acceptable level of quality.

The paper of Assaf et al. (2009) presents concepts of environments just-in-time learning/collaborative that use a blended learning strategy, in which the principle of personalisation plays a strategic role. The study presents the contributions embedded in performing the customisation of online learning services to the electronic business management section (ebMS) community. For the case study, ebMS was composed of teachers, outside researchers and learners of Southern Mediterranean countries and the results they demonstrate the feasibility of using one personalised learning model and application to the learning processes and services embedded in the technological platform sustaining the ebMS learning community, which was called Virtual ebMS.

The work of Filho and Agoulmine (2010) examines the conflicts that can be generated in gathering information to support decisions of adaptive applications. The authors explain that the QoC parameters can be used to perform these tasks, seeking to resolve internal and external conflicts based on two indicators: the probability of correctness and reliability.

Besides the presented works, it can also be cited some other papers such as Sheikh et al. (2007), Pawar et al. (2007) and Fanelli et al. (2011).

After an extensive review of the literature involving the application of QoC in different application domains, the results obtained made clear the paucity of solutions present in the educational field, which makes innovative the development of this work and a differential in relation to the existing applications. The papers presented cover different application domains, as vehicular networks nodes, smart homes, scenes of natural disasters, among others, while this work is focused in education with the use of VLEs. Another aspect that should be emphasised is the detailed study that was conducted to identify the largest possible number of QoC parameters in the literature, being performed the individual analysis of each of these to identify which suited the context of this work and could be applied in the environment. In the other studies analysed, the QoC parameters used by the authors are presented in very small numbers, being specific to the proposed research topic, not performing an identification of all the parameters that could be applied in the proposed systems, i.e., authors delimit the parameters to be used to perform initial tests.

3 Theoretical basis

In this section is presented a theoretical basis on the main topics addressed in the development of this work. In the following part are presented the concepts related to the areas of context and QoC.

3.1 Context

One of the areas of research within the scope of U-Learning is context-aware computing. It is a relatively new research topic in which various types of computer applications have been developed for different domain areas. According to Knappmeyer et al. (2013), the context area can be seen as an interdisciplinary field of research comprised of fields such as Artificial intelligence, mobility, human–computer interaction, etc., in which many studies have been conducted to overcome existing challenges.

The definition formulated for the term context has been discussed by different researchers in this area, and the concept that has been widely used by the academic community was coined by Dey (2001), presented in Section 1. Other authors have also discussed this definition and proposed different views about this term.

Knappmeyer et al. (2013) understand that context is any information that provides knowledge and characteristics of an entity (user, application/service, device or smart places), which is relevant to the interaction between the entities themselves and with the digital world. In a more delimited approach, Sheikh et al. (2007) define the term as information that directly or indirectly describes the situation of a human being.

A system that uses context information to provide some kind of service to users, e.g., to adapt its contents and tools according to user's preferences, can be considered as a

context-sensitive environment. For Baldauf et al. (2007), such environments are able to adapt their operations to the current context without explicitly requiring user intervention, thus seeking to maximise their usability and effectiveness, while taking into accounts the environmental context. Examples of possible applications are travel guides, restaurants, smart homes, etc.

Context information that can be used in an adaptive environment includes user's cognitive profile, type of device, their connection speed and global location. In this work, context information related to users cognitive profile, their connection speed and type of access device were selected as components of the user context to be used in the adaptive environment.

3.2 Quality of context

A system that uses context information to provide some kind of service to users, e.g., to adapt its contents and tools according to user's preferences, can be considered as a context-sensitive environment. As discussed in detail in the works of Baldauf et al. (2007) and Zheng et al. (2011), existing systems seldom consider QoC information, which is ignored or poorly handled. For this reason, QoC was chosen as the subject of this research, which addresses context in a Moodle-based adaptive environment.

The term QoC is defined by Buchholz and Schiffers (2003) as any information that describes the quality of information that is used as context information. For Manzoor et al. (2010), QoC indicates the degree of conformity of context collected by the sensors to the situation prevailing in the environment and the requirements of a particular context consumer.

As discussed by Henricksen et al. (2002), context information is: incorrect if it does not reflect the true state of the world that it is modelling; inconsistent, for example, if it contains contradictory information; incomplete if certain aspects of the context are unknown. Here is one example of a problem: a situation in which the user is using the application in a certain place and moves to another floor or building; if there is no treatment of quality, the context of location and/or profile that displays their preferences for nearby places to visit will quickly become out of date and may impair its interaction with the application.

Thus, a context-sensitive system must address the quality of information as a very important requirement that will influence the adaptation of the environment. If not treated, the environment will not be able to assess the quality of the information used and may cause unwanted changes to user's preferences and needs.

For measuring the QoC that is used in a system, rules or indicators that are called quality parameters can be applied. According to Santos (2006), each parameter is described by one or more appropriate quality metrics that define how to measure or compute the QoC against the parameter, where the metric contains a value, a type and a unit.

The use of QoC parameters in the environment aims to obtain assurance that the context information collected conforms to user's preferences and needs. According to Nazario et al. (2012), QoC does not require context information to be perfect, with the highest possible accuracy and timeliness, but that there must necessarily be a correct estimate of the quality of information.

Research conducted by different authors, such as Sheikh et al. (2007), Buchholz and Schiffers (2003), Manzoor et al. (2010) and Nazario et al. (2012), showed no standardisation

for nomenclature and definitions to those parameters; many authors defined a set of parameters, often with different names and the same or similar meanings. One example is the definition of the of Up-to-Dateness and Timeliness parameters, which are used in different works by the same author, but whose meanings are the same.

Thus, the selection of quality parameters can be considered a complex task to be accomplished, given the large amount of existing parameters, as well as the similarities between them, which can make such choice more complicated. In addition, according to Nazario et al. (2012), the same happens to alternatives for quantifying these parameters, i.e., groups of authors define different ways of quantifying one or more parameters that they use.

Thus, previous studies on quality parameters were reviewed in order to select those best suited to the types of context information used in the present study, namely cognitive user profile, user's connection speed and type of device used for access. Thus, 12 parameters were selected; Sections 4 and 5 describe them and explain the way of measuring them.

The following parameters were not selected; they were discarded because they were not considered suitable for the scope of this work: Resolution, Accuracy, Timeliness, Trust-Worthiness, Refresh Rate, Certainty, Consistency Probability, Age, Temporal Resolution, Spatial Resolution, Significance, Integrity, Reliability, Usability, Sensitiveness, Data Retrieval Time and Security.

This was due to the fact that they are very similar or have the same meaning as other parameters already used in the environment. Another aspect that should be stressed is the large number of parameters that were discarded because their use is linked to location context, which is not used in this work.

This shows the difficulties above-mentioned; in different papers, several authors defined the same parameters with different names and with few modifications compared with existing ones. This complicates the step of selecting the parameters that can be used for verification of context information present in a context-sensitive environment.

4 Methodology

This project was developed to provide students with an adaptive environment to their preferences as regards cognitive profile, connection speed and type of device. Quality parameters were applied on the context formulated for users, in order to create greater assurance of a correct adaptation and improve interaction between users and the environment while they perform their educational activities. The developed environment was defined as Ubiquitous VLE with QoC ($UVLE^{QoC}$).

U-SEA (Piovesan et al., 2012) and SEDECA (Mozzaquatro et al., 2009) modules, which collect context information about connection speed and cognitive user profile, were used as the basis for developing this project. They were restructured for optimisation of their operating mode and their concurrent execution in the $UVLE^{QoC}$ environment, because in its first version, they were created in environments with different versions of Moodle.

Based on the mode of operation of these two modules, the use of AH aimed to make changes in the presentation of contents (e.g., slides, video files, images) and tools (e.g., chat, forum) in each course of $UVLE^{QoC}$. According to Brusilovsky et al. (1999), AH encompasses every hypertext system and/or hypermedia that reflects some features

of its different users in models and applies these models in order to adapt various visible aspects of the system to the needs, desires and preferences of each user. To perform these operations in UVLE^{QoC}, the AH technique known as Fragment Variants was applied concomitantly with explanation variants method; both of them will be described in detail in Section 5.

Given these settings, QoC and its respective parameters were reviewed, analysed and selected for the treatment of context information collected from the environment. The selection of the parameters used in this study was based on an analysis performed to determine which of them matched the types of context information used by the environment, namely cognitive profile, connection speed and type of user device.

The following quality parameters were applied in the context information present in the environment: Up-to-dateness; Completeness; Access Right; Freshness; Coverage; Repeatability; Frequency; Precision; Delay Time; Representation Consistency; Precision. After these parameters were set, the metrics for each one of them were also defined in order to quantify them and verify that they were valid and, thus, establish that the respective information can be used in the formulation of user context.

The adaptation of the interface according to context information about type of user's access device was based on a study by Voss et al. (2013) on existing technologies involving Moodle, in order to effect such action in UVLE^{QoC}. The results of this study pointed to the use of the Bootstrap theme when access to the environment is executed via mobile devices (Smartphones and Tablets). For the development of the environment, the technologies used Wamp (http://www.wampserver.com/), which includes Apache to host environment, the programming language PHP and the MySQL database that are present in Moodle (https://moodle.org/), whose version was used at the time the 2.5.1+.

Assessment of the environment occurred with users who have formed a group of 12 students attending undergraduate and graduate classes in Computer Science in a federal university. The following mobile devices were used: tablets and smartphones, with '4 and 10' screens, respectively, as well as a 14 screen notebook for access to the environment. Broadband connection was used both on the notebook and on the Galaxy S3 Mini mobile phone, while 3G mobile data network was used on the tablet as well as on the Galaxy S3 Mini mobile phone.

In order to measure the tests that were executed, there was applied a questionnaire to evaluate the use of the environment by the users, which involved specific aspects of the modules developed containing 11 multiple-choice questions and two essays. To measure the final results, Likert (1932) scale was used. This questionnaire has also been evaluated by a technique known as Alfa of Cronbach (1951).

5 UVLE^{QoC}

The proposed work aimed at developing a ubiquitous VLE, in which quality parameters on the context formulated for the user were applied in order to create greater guarantees of proper adaptation. The context is formed by their cognitive profile and technological context (device type and connection speed), modifying the materials and tools according to its preferences. Thus, it was necessary to perform some steps, which are described below. Firstly, information is collected to start the formulation process of the user's context and adapting the environment to suit their preferences. The collection of context

information is held by the two integrated modules on UVLE^{QoC}: SEDECA 2.0 and U-SEA 2.0.

SEDECA 2.0 identifies student's cognitive profile, which may be Holistic, Divergent, Serialist or Reflective, upon application of a 16-question questionnaire on their first access to the environment. The module defines user's profile and their preferences for contents and tools, and then adapts the environment.

Users can choose their two preferred types of material (Paper, Book, Slide, Image, Video or Link); if the first is not available, the second is presented. The communication tools available are Chat and Forum, while the tools of activities to choose from are Lesson, Questionnaire and Task.

After user's cognitive profile is defined by the SEDECA 2.0 module, they can access the main page of Moodle, which lists the courses available in the environment. When accessing a course, the U-SEA 2.0 module identifies the computational context where users are, by checking their connection speed, which is measured by sending a 100 KB file from the server to user's devices.

The rules for adapting the materials in the environment according to user's connection speed were based on a study by Piovesan et al. (2012). If the speed is below 500 Kbps, only files smaller than 400 kb are shown to users; these files are referred to as adapted. If the speed is greater than 500 Kbps, files referred to as not adapted are shown in the course, i.e., only files larger than 400 kb.

With the capture of information about the cognitive user profile and its speed connection, the user context can be formulated and the adjustments in the discipline can be done. However, before this occurs, the Quality Context module performs certain checks to create greater assurance that the context is formulated according to the needs and preferences of the user.

5.1 QoC module

Use of the parameters of QoC in the environment aims to obtain assurance that the context information was collected according to the user momentary situation. To achieve the goal of implementation of QoC, twelve (12) parameters were selected, as shown in detail:

Up-to-dateness: according to Buchholz and Schiffers (2003) it is specified through the addition of a time-stamp to the background information, therefore, it is necessary a synchronisation time between the source and the sink of context. According to the author, this can be determined, by requesting the information from current context or through the installation of a service event in source of context, updating reliably the context information, if the current context value differs significantly from the information of context. If the current value context differs significantly from background information previously supplied.

The calculation for this parameter was defined by Manzoor et al. (2008) as follows:

$$\text{Age}\ (O) = T\text{curr} - T\text{meas}.$$

Tcurr: Current time, captured at the time the check is carried out. Your type is DATETIME with the date in the format xx/xx/xxxx and the time in the format 12:00:00 AM.

Tmeas: the time was measured for the first time that the background information was used. Your type is DATETIME with the date in the format xx/xx/xxxx and the time in the format 00:00:00.

$$\mu = 1 - \frac{\text{Age}}{\text{Lifetime}}.$$

Lifetime: the time of life that the information can have. For example, it can have 3 min of lifetime.

The closer the value is of 1, the better the situation of the information to be used in the formulation of the user context. If it is more close to 0, then this means that the information is not adequate to be used, because it may be out of ate.

In this work, its application is given in the user's connection speed, at each update it performs a check-up, if the value is equal to 0.3 or less, the connection speed should be measured again. Otherwise, it will be used in the environment.

Because of this, the context information lifetime will be 5 min; it means that, if it is 3.5 it should be measured again. This value was estimated based on the authors' empirical knowledge, since that the precise information lifetime measurement is a very complex process, in which there are not concise studies to assume a correct value.

Through the tests it was verified if the values satisfy the users' needs, by analysing the usability of the environment on their own. So, it is possible to estimate if the stipulated amount is appropriate in the formulation process context and it does not bring environment use difficulties for users.

Taking the cognitive profile in consideration, using the same estimation process described above, the verification is applied to the questionnaire, wherein the lifetime is 2 months. Every time the user logs into the environment it is checked if it has already answered the questionnaire, if it has already answered, then it will be checked if the information is still valid.

When it reaches 0.3, it means, when it has 42 days of life, there must be showed a message asking if the users wants to verify his profile again, if he does not answer until the 60 information day of life, he will be obliged to say if he wants or not do the cognitive profile again.

Completeness: This quality measure shows the amount of information that is provided by a context object Manzoor et al. (2008). Zheng et al. (2011) explains that the completeness of a context object is calculated as the ratio between the sum of the weights of the attributes available to a context object, and the weights sum of all the context object attributes.

This parameter's calculation is defined by Manzoor et al. (2008) as it follows:

$$C(O) = \frac{\sum_{j}^{m} = wj(O)}{\sum_{i}^{n} = wi(O)}.$$

It is used in the speed connection and in the user's profile. It will be checked when a selection of these information in the database is performed, analysing if all information are arranged, there can be no empty information (null).

$N = 1$ attribute (connection speed).

$Wi = 1$ − maximum or essential.

In the connection speed, the maximum weight is 1 and there is only 1 attribute (speed), which is essential to the operation. Then the value can be 0 or 1, where 1 is the same as the full information and 0 is the same as the incomplete information, which should be measured again.

In the cognitive profile, the maximum weight is 7, so, all attributes have to be present, if one of them is not present, the information cannot be used, because it will not be complete. So, if the value does not equal 1, it means that it is not complete and cannot be used.

Access Right: shows the extent to which the information owner allows the context consumer to access the information (Manzoor et al., 2010). Access to certain pages can be restricted to ensure that the user' context will not be affected.

> If it is equal to 1 means that the user has access to information and can view and edit.
>
> If 0, do not have access. This will be verified based on the type of user.

Freshness: lifetime is used as a context temporal indicator that is being detected from the environment. This parameter reflects the maximum time that the context goes through to the consumers Zheng et al. (2011). Sheikh et al. (2007) explains that it refers to the time from the context information determining to the time it is delivered to the consumer.

In this work, this parameter is related to the time break between the search for context information in the Moodle database and the information presentation to be used in the homepage adapting according to the users preferences.

The time for it happen is 1 min, i.e., within 1 min the system should make the select and present information. If it is not in this range, it may mean that changes have already occurred and the information selected after 1 min may be outdated. Its choice is also based on the authors' empirical knowledge, as there was a difficulty in measuring an accurate value, given the absence of specific studies within this scope.

Coverage: the amount of detected potentially context on which the information is delivered (Cronbach, 1951). Nazario et al. (2012) defines coverage as the set of all possible values for an attribute context.

On the connection speed, it was determined by the author that the values that represent <50 Kbps connection will not be considered valid, because this represents a very low speed, even if considered for a dialup connection speed of 56 Kbps, which results in an extremely limited environment use. Talking about the maximum limit, there was not stipulated limits for speed values, since a connection speed may have high values. This check is done before inserting the value in the database, if it is less than or equal to 50 Kbps, a new calculation should be performed, otherwise it may be used.

Repeatability: refers to the measurement stability over the time (Huebscher and Mccann, 2004). The context information captured during a certain period of time can be used as the basis of information and there can also be calculated averages for certain specific purposes. At every log in $UVLE^{QoC}$, the connection speed can be measured several times in order to examine if there is stability checks or if there is a wide variation. If there is a variation, problems may occur in the adaptation of the materials to be shown; as

a user of low connection may have had a connection speed recorded inaccurately, with the verified stability help it will be possible to verify if errors are happening.

For measurement, it must be done a speed average, which is included in database in each 5 min, and verify if the new speed stored is very different from the average. If it is, new speed measurements must be done until it reaches three checks.

If after these three checks, the value keeps the same and out of the speed average, it means that the value is correct and stored. One example of a very big difference is if the average is 200 Kbps and the verified value is 15 Mbps, that means a very big difference between the speeds and that it has to be analysed. A maximum deviation of 50/from the average was established by the author to be verified speed if the amount is higher than the deviation.

The cognitive profile will be measured periodically or when the user wishes. If there are many modifications in the type of user profile, a message will be sent via Moodle environment for him, in order to verify if there is any problem with the cognitive profile that is being defined, for example, if the materials displayed according to his profile are not meeting his needs, and the environment adaptations are according to his preferences.

Frequency: The frequency defines how often the information needs to be updated (Nazario et al., 2012). It is related to the context information that are very dynamic, as the user's location, where time breaks can be assigned, since this information must be updated to create greater assurance that the context is correct.

Information about the user's cognitive style need to be updated at a predefined frequency. Thus, a time interval of 2 months was set to be updated, as seen in the variable lifetime of up-to-dateness. This value setting was based on the author's empirical knowledge.

It was determined that the speed will not be measured at every page refresh, but based on its lifetime, i.e., at each 5 min frequency, the connection speed will be checked, as described also in Up-To-Dateness parameter.

Precision: it measures the precision on how context information describes reality, as for example, location precision (Gray and Salber, 2001). It can also be defined Filho and Agoulmine (2010), as the details level in which the context information features the real world.

According to Zheng et al. (2011), talking about numerical information, which is used in the connection speed measurement, authors say that a value described three significant figures (32.2) is more precise than two significant figures (32).

Aiming at using and establishing an appropriate level of accuracy in measuring the speed, there was established a measurement using two decimal places after the comma, instead of using integers. One example is that 20 Mbps is considered wrong, while 20.49 Mbps is considered right.

Probability of Correctness: this parameter denotes the probability of a piece of context information to be correct (Buchholz and Schiffers, 2003). According to Bu et al. (2006), due to limitations of sensor technology, is difficult to guarantee the accuracy of the detected data. However, if the context is measured by means of random sampling in an extended period, with the registration of the correct rate (the probability that the contexts in computers match situations in the real world), it is possible to provide a quantitative measure for the quality context on a context-sensitive system.

The speed measuring connection may be performed by sampling, or by means of set periods based on the lifetime of the connection speed. Thus, there are records and the average connection speed of the use, and the user can use it to denote the connection speed in case of measurement errors. This measure allows the establishment of long-term increased possibility that the speed of connection is identified within the average that the user has and so to use them in cases where measurement is not possible.

Delay Time: it is the time interval between the time when the situation occurs in the real world and the time when the situation is recognised in the computer (Bu et al., 2006). In connection speed, it is the time between the moment the speed is calculated and generates its result, and the time when this result is inserted into the database and used as context information. The following example demonstrates the use of this parameter:

Initial time: 14:29.

Time it is inserted and used in BD (final time): 14:32.

Maximum time: it was defined that the maximum time will be 5 min.

$$D = \frac{TF - TI}{TM}$$

The result of the calculation in the example is 0.6 s, that is, if the result is equal to or higher than 0.7, then the time is too long and the information may be outdated, then a new measurement must be performed. If the result is <0.7, then the delay has little information and may be used.

Based on the author empirical knowledge, a time of 1 min was set for this information to be generated in the correct format and stored in the database. The tests that were done help to verify the defined value validity.

Representation consistency: the measure in which the context representation format is consistent with the requirements of consumers (Manzoor et al., 2010). Combined to the accuracy stipulated in Zheng et al. (2011), which are used in two decimals after the comma, the Representation of Consistency checks if the data format conforms to the require one in order to form the users context.

On the connection speed, the format should be the numeric type float for speed and precision timer with seconds to the timer. On the cognitive profile, they all should be in the numeric format type Int, but the timer which should be accurate to the seconds.

Priority: Priority is derived from the user class quality and aims to allow differentiation of traffic when multiple data must be sent (Fanelli et al., 2011).

So, it should always be measured first the speed of connection and sought after in the database information from cognitive profile, because when files are uploaded, they are brought in line with the profile. So if the speed has not already been calculated, it cannot bring the adapted files and show, or having to look after the files, performing a new selection because the speed is low, as there may be delays in its measurement, so it is a priority in relation to the profile.

With the quality parameters selection, it was possible to establish which ones could be used in this work, which have context information related to the cognitive user profile and its connection speed, and discard the other parameters that do not fit to be used in the environment.

5.2 Moodle adaptation for mobile devices

For adaptation to mobile devices, the choice of the Bootstrap theme for use in this work was based on a study conducted by Voss et al. (2013) about existing mobile technologies for adaptation in the Moodle environment. There are three types of solutions: MLE-Moodle, Moodle Mobile and Bootstrap.

MLE-Moodle was not used because of its specific type of access, at an address other than the one where the traditional Moodle is hosted. In addition, MLE-Moodle is not compatible with Moodle version 2.0 or higher, and version incompatibility prevents the use of the solution in this environment. Moodle Mobile, in its turn, was discarded because it requires installation on user's devices and the respective configuration.

Bootstrap theme, which is a kind of framework formed by cascading style sheets (CSS), can be integrated with Moodle environment in the plugins section, in which it is inserted as a theme. With its installation performed, the interface settings to be presented can be made for different types of devices.

Bootstrap provides an automatic adaptation for mobile devices, i.e., when users access the environment, it automatically identifies the type of device and adapts its interface. If the device used is a tablet or laptop, the Bootstrap theme is selected and presented to users; otherwise, if the environment is accessed with a laptop or desktop computer, Moodle's™ default interface is maintained.

It should be emphasised that it is important to use the rules of QoC in the adaptation for mobile devices, such as a shift in the type of connection, in which the QoC parameters detect this change and assess user context again to measure the connection speed and check that the resources presented match the updated context. These checks ensure that users are constantly under observation and provide greater assurance that the context information used in the environment reflects its momentary situation and allows appropriate interaction between users and the environment.

5.3 $UVLE^{QoC}$ implementation

$UVLE^{QoC}$ is hosted on a machine with public IP address for access by users, which is installed Wamp 2.2 (Wamp, http://www.wampserver.com/) application, which has a set of tools to assist in developing systems. Among these is Apache 2.4.4, a local server that hosts the $UVLE^{QoC}$ and enable it access.

The database management system (DBMS) MySQL 5.6.12 is also coupled to Wamp, which is located in the Moodle database, where the data of the environment, as well as tables and attributes that store the information are stored context related to the cognitive style of the user, the connection speed, the types of materials included (full text, video, slides, etc.) and users favourite tools (chat, forum, etc.). Moreover, the language PHP 5.3.13 is available for development and code editing in Moodle environment, which was built using this language.

Moodle (Moodle (https://moodle.org/)) environment was selected because it is widely used by researchers and users in different locations around the world, and is free and open for editing code. The version used was 2.5.1+, which was the latest at the time of the development environment.

At first, information is collected to start the process of formulation of the user's context and the environment is adapted to suit their preferences. The collection of context

information is held by the two modules previously described: SEDECA 2.0 and U-SEA 2.0.

SEDECA 2.0 deals with the identification of students cognitive profile, in which through a questionnaire, it sets the user profile (Holistic, Divergent, Serialist and Reflective), their preferences regarding the content and tools, performing environment adaptations .The questionnaire is necessarily applied to the user at the time of their first access to the environment, i.e., to perform the first login, they will have to answer the questionnaire in order to have access to other pages of the environment.

SEDECA 2.0 questionnaire has 16 questions about the user's profile, four questions for each of the four cognitive styles used in this environment. In addition, three questions are arranged on the user preferences regarding the types of materials, tools and activities that are performed in Moodle.

The user can choose the preferential type and the secondary material (Paper, Book, Slide, Photo, Video or Link), in case the preferential one is not available, the secondary one will be presented. The communication tools available are the Chat and the Forum, while the tools of activities to be chosen are Lesson, Questionnaire and Task.

With the user cognitive profile defined, he can access the main page of Moodle, which are listed in the disciplines available in the environment. When entering a discipline, the U-SEA 2.0 performs the identification of the computational context, in which the user is inserted by checking his connection speed, which is measured by sending a file from the server to the user's computer with a 100 KB size.

The size of this file was chosen as Piovesan et al. (2012), by not interfering with the user connection speed. At the time of posting, a timer is started to measure the time of his transfer, being held after the submission, a calculation of the file size over time, resulting in the user's connection speed.

The rules for adapting materials in accordance to the user connection speed environment were based on a study on the work of Piovesan et al. (2012). If the speed recorded is <500 Kbps, only files with <400 KB size are presented to users, and they are called adapted. If the speed is higher than 500 Kbps, the files named as not adapted are shown in the subject, it means, those that are higher than 400 KB.

By capturing information about the user cognitive profile and his connection speed, the user context can be formulated and the adjustments made in the discipline. However, before this occurs, the Quality Context module performs certain checks to create higher assurance that the context is formulated according to the needs and preferences of the user, as shown below:

- *Up-to-dateness*: if the link speed has a shorter lifetime than 5 min and the definition of cognitive profile is <2 months, then the context information may be used. Otherwise, a new peed checking should be performed, and/or the user's cognitive profile must be redefined.
- *Completeness*: if all the attributes of the information about the user's cognitive profile and connection speed are filled, then these can be used. If not, further checking should be performed to fulfil those which are absent.
- *Freshness*: the time in which information is selected and becomes available to be used in the environment is checked, if it is <1 min, then it can be used. Otherwise, a new information selection is held.

- *Coverage*: the range limit time for the user connection speed to be considered is higher than 50 Kbps, i.e., all speeds below this value will not be considered, thus new measurements must be performed.
- *Frequency*: according to the Up-To-Dateness, the frequency with which the context information should be updated is 5 min. Regarding the user cognitive profile, a new scan should be performed after 2 months.
- *Precision*: the connection speed format that should be presented in the discipline is decimal, with two significant figures and two decimals after the comma.
- *Delay time*: if the time period between the connection occurrence speed and its recording in database is valid, then it can be inserted. Otherwise, a new checking should be performed.
- *Representation consistency*: the formats in which information is presented are verified, such as the speed and the date it is verified, so the data related to the cognitive profile. If they are in accordance with the established rules, they can be used, or a new selection must be done.
- *Priority*: the connection speed is first checked to load all the files according to it, and later there is done a selection of the files that will be presented in the discipline.

The checks are carried out during the user context formulation, i.e., the moment he access the discipline. Thus, the adjustments to the content and to the tools in the discipline are done only after all of parameters have been verified and all proposals conditions are valid.

In addition to these checks performed dynamically when the user accesses the discipline, other parameters are used during their interaction to verify aspects concerning QoC. The parameters are the following ones:

- *Access right*: the questionnaire can only be answered by users like students, other users have no access to this page.
- *Repeatability*: the connection speed stability is checked through the history and the average speeds calculated. Likewise, the cognitive profile is stored and checked whether there are changes in the profile type defined by the user. So, it is possible to check if there are many variations in the data and take decisions to solve problems that can exist.
- *Probability of correctness*: enables the data to be used on the connection speed for an average trace, which can be used in situations where the context cannot be formulated, even after further checks are performed, as may occur in up-to-dateness, freshness and precision.

All checks involving the quality parameters are carried out aiming at creating higher assurance that the context created to the user shows it current situation. Thus, if the whole process is in accordance with these rules previously established, the user context is formulated.

With this information, the environment performs the adjustments using the AH, in which the explanation Variant method was used, being implemented by the variant fragment technique. This technique application in the environment is used to provide different

concepts in the same page, in the disciplines, they are topics or weeks. Those had different variant fragments, it means, a variety of different types of materials and tools in each week or topic.

Thus, using the context information the materials and tools presented in the discipline page are adapted through the variant explanation method. This method is to show or hide parts of the information, providing only the parts that are of the user interest.

Figure 1 shows the home page of the course without having any kind of adaptation, demonstrating how was the operation of the environment before the proposed adjustments were done. In this case, the user context is not considered and all materials and tools available in the discipline are presented to the user.

Figure 1 Environment without content adaptations (see online version for colours)

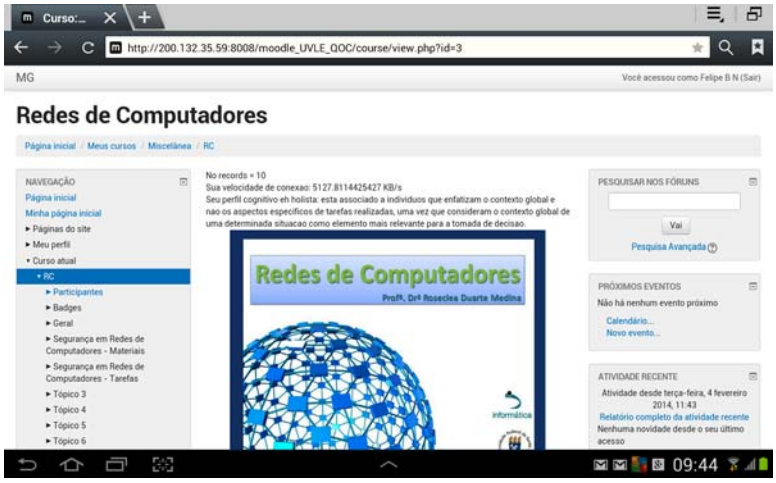
In Figure 2, it is shown the environment with the proposed adjustments, changing the way of content and tools presentation, unlike the figure previously shown. Book resources and links have been hidden, there was only presented the videos and papers that were of the user preference. Another aspect is related to its speed, there are only presented materials which are not adapted, i.e., those with higher size than 400 KB because its speed is higher than 500 Kbps.

At the moment the user accesses the VLE, the environment is adapted according to the user's device type. Automatically, the environment identifies if the access is being done via mobile, tablet, notebook, among others, and according to the rules previously established and it adapts its interface using the Bootstrap theme or it keeps the Moodle default layout.

Figure 3, the access was performed using Tablet, whose screen size is 10' with Wi-FI connection, which presented the discipline homepage. All features present in the Moodle standard interface, are also available in this adapted layout, since the Bootstrap theme modifies only the appearance, without changing the environment's resources.

Figure 2 Environment with content adaptations (see online version for colours)

Figure 3 Environment with Bootstrap interface on a tablet (see online version for colours)



It is possible to see that the environment interface fits user's device screen size. The environment homepage is arranged to facilitate the user interaction with it, such as inserting buttons with larger sizes and appropriate layout to the device screen.

6 UVLE^{QoC} evaluation

A questionnaire with 11 subjective questions and two observation fields was designed to evaluate the performance of four integrated modules to Moodle environment (SEDECA 2.0, U-SEA 2.0, QoC and Mobile Device), which should be answered by the users based on their perceptions while using the environment.

The evaluation was conducted with members of a group of 12 people with advanced knowledge in computing, and the following guidelines were suggested for interaction with the environment: access the environment and respond to the questionnaire about

SEDECA 2.0 to define their cognitive profile as users; access the course entitled 'Computer Networks' and verify whether or not the information about their profile and connection speed was shown; observe whether the materials and tools were adapted according to the connection speed displayed and their cognitive profile; check whether the informed rules about QoC parameters were operating as specified; access the environment via a desktop computer and a mobile device to observe the adjustments to the contents and the interface.

Likert (1932) scale was used to measure the response options, ranging from 'Strongly Disagree' (1) to 'Strongly Agree' (5). Figure 4 shows the results obtained with the answers provided by users in the questionnaire about the operation of the modules. Both the mean of the values for each question and the mean of responses per user were calculated, which resulted in an overall value of 4.36.

Figure 4 Average questionnaire answers done with users (see online version for colours)

Question / User	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Average
User 1	5	5	5	5	5	5	5	5	5	5	5	5,00
User 2	5	5	5	5	5	5	5	5	5	5	5	5,00
User 3	5	4	5	4	2	4	5	4	4	3	3	3,91
User 4	5	3	5	3	4	4	5	1	3	3	3	3,55
User 5	5	4	5	5	4	5	5	5	5	5	5	4,82
User 6	5	5	5	3	5	5	5	5	5	5	5	4,82
User 7	5	3	5	1	2	1	1	1	5	5	1	2,73
User 8	5	4	5	1	3	2	5	2	5	5	3	3,64
User 9	5	5	5	5	5	5	5	5	5	5	5	5,00
User 10	5	3	5	2	3	5	5	5	5	5	5	4,36
User 11	5	5	5	5	3	5	5	5	5	5	5	4,82
User 12	5	5	5	5	5	5	5	5	5	3	3	4,64
Average	5	4,25	5	3,667	3,833	4,25	4,667	4	4,75	4,5	4	4,36

Questions 1 and 3 verified if the context information related to user cognitive profile and it connection speed have been available for the user in the environment, in both the maximum score was reached. It shows that in all cases there was not a failure in the collection process, in the formulation and in the presentation of the user context, which means that the QoC parameters worked properly even though there were some problems in the user context development, the inserted rules helped to solve this, as a consequence the information has been presented.

In question 2, it was addressed whether the user cognitive profile was consistent with the users preferences, in which most of the users pointed out that agree with the type that has been established for them, only two users marked answer 3, that means they doubt if the cognitive profile set by the environment was really according to their characteristics.

Question 4 presented several variations on the answers provided, half of the users indicated that they totally agree with their connection speed displayed, while the other ones attributed grades 1 and 2 to the calculated values, which means that there might have occurred fails in the definition of the user's connection speed. In order deeper the problems, the observations made by users with regards to this problem have been verified.

In three comments, users reported that their connection speed was not measured correctly; being at all times used a mobile data connection 2G or 3G network. It is

believed that due to instability in the existing mobile data network 2G and 3G, as already found in several parts of the country, there was this variation in the connection speed values, even with the use of QoC parameters. Thus, it must be necessary to perform more thorough and with a larger number of users analysis to check what problems occurred when verifying the speed in this type of connection.

Question 5 evaluates if the materials and tools in the environment were presented according to the user's cognitive profile (SEDECA 2.0), in which results that are considered intermediate have been reached, as explained in software testing involving this adaptation process, only part of the material was being adjusted. Thus, the assigned grade reflects that adaptations occurred, but within consistencies, such as the presentation of other material besides the preferences reported by users.

In question 6, it was checked whether the U-SEA 2.0 performed the adaptation of the materials in a consistent way with the users connection speed at the time of their access to the discipline. The great majority of responses were positive, i.e., the materials presented were consistent with the users connection speed. However, in both cases low grades were highlighted, with the same users who had reported on comments that have not had their connection speed measured correctly, therefore because of this problem, the adaptation of the materials was incorrect.

Questions 7 and 8 were specifically about the QoC parameters, in which satisfactory results were verified, which results in the appropriate rules operation in the QoC parameters applied in the environment. As in Question 6, the problems that happened with the two users also affected the functioning of the parameters, since they are directly connected with the connection speed, which eventually also hinders the functioning of these parameters.

In questions 9 and 10 aspects related to environment adaptation using desktops were addressed, notebooks and mobile devices were the main aspects discussed (Tablets and Smartphones), which were addressed to the automatic verification of the type of device and the user interface selection to be presented was satisfactorily and predominant. In the cases were the grade 3 was attributed, as willing comments, the interface selection was perfectly done and predominant, however the interface did not fit completely to the device screen size, so it was necessary to use the scroll bar to view all the content.

In the end, question 11 shows that the proposed environment changes happened even when a mobile device has been used; it means that in despite of the interfaces used in the environment, the modules have done all proposed changes. Moreover, the answers obtained about the proper presentation of the materials according to the cognitive style and connection speed were considered satisfactory, even with the problems that have been discussed before. Figure 5 shows a graph with the answers provided by 12 users who responded to the modules.

It can be seen that the response curve generally continued to be concentrated on the axis corresponding to reply with a value of 4, which means in a bigger picture, a positive feedback from the users pertaining to the developed modules. It is noteworthy that, although the overall results have been positive, in the responses to the questions 4, 5 and 8, the curve obtained a decrease due to low ratings provided by the users, due to difficulties involving the topics covered in these three questions, as described in the previous paragraphs.

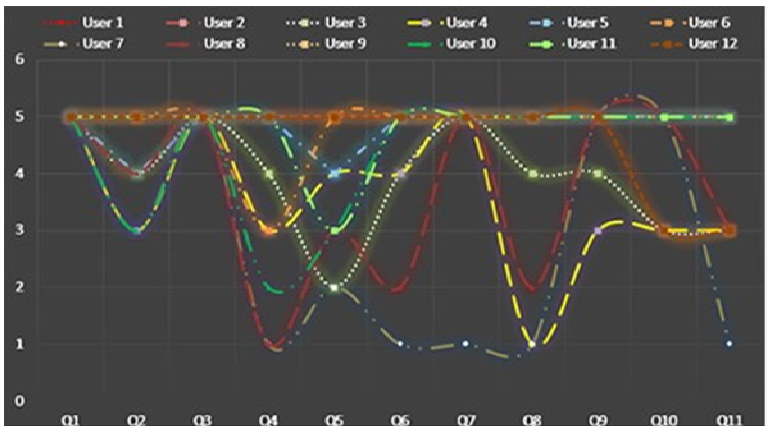
Based on the analysis of responses and also on the comments made by users, and taking into account the overall assessment of the environment, the final average of 4.36 for all collected answers is deemed as satisfactory and positive, because this was the first

user assessment of the environment, and the first tests with integrated modules were performed with this particular kind of user. Cronbach's alpha coefficient (Brooke, 1996) measures the correlation between responses on a questionnaire by analysing the profile of the answers given by respondents.

In a study conducted by Bevan et al. (2003), he defined that there is a magic number of five users for use in a usability test. However, an analysis by Faulkner (2003), demonstrated that it is necessary that the number of users is representative. Following these lines, it was established as a goal, a minimum of five people to conduct the evaluation of the environment, resulting in the tests by 12 users. It was also verified through a review of the literature that there is no minimum users required to calculate the coefficient alpha, but it is known that if the number of users is high, it gives more consistent assessment.

The result of the coefficient can be adjectives according to a scale of values previously defined (Hora et al., 2010). The result was a coefficient alpha = 0.8823317621454545; thus, the reliability of the questionnaire can be classified as 'good' on the scale of values. This result provides greater assurance that the questionnaire administered to the group of users was valid and the values entered by them can be considered as reliable as regards the assessment of the environment.

Figure 5 Environment without content adaptations (see online version for colours)



7 Conclusion

Use of VLEs is constantly evolving. Teachers and students of various institutions worldwide are adapting and modifying their traditional style of teaching, so as to include the use of technology to support their activities. Using U-Learning environments that are based on Moodle or have independent implementations are an advantage in the scenario proposed with the use of this technology.

One aspect that has to be considered in U-Learning environments are the context information, since they are very volatile, which can result in an inappropriate environment resources adaptation to the user preferences due to the lack of information updating or because of inaccuracies in their acquisition. So, the users can feel unmotivated and even create rejections regarding the environment usage, considering that it changes in an inappropriate way to the user's momentary situation.

QoC parameters use that was proposed in this work address exactly this problem, in which is application aims at creating better guaranties that the formulated context will be updated and the closest it is possible to reality.

With UVLE^{QoC} development, a Moodle environment that could provide the adaptations to the users context (cognitive profile and connection speed) according to their preferences and needs, in which the QoC parameters have been inserted aiming at creating higher guaranties to make it happen. Another aspect that was also taken in consideration were the existing difficulties when VLE has been accessed on mobile devices, being proposed an automatically adaption to the users device screen size.

As contributions it is possible to elicit: SEDECA 2.0 specification, modelling and implementation. U-SEA 2.0 module specification, modelling and implementation, extensive book reviews about the QoC subarea to map the biggest number of exiting parameters, presentation of the difficulties involving the QoC area, QoC specification, modelling and implementation, mobile adapting technologies available for VLE Moodle were analysed, UVLE^{QoC} specification, modelling and implementation and its evaluation done by the group of users who answered the questionnaire.

It was also possible to demonstrate the feasibility of adapting an U-Learning environment to suit the requirements involving QoC. Thus, the paper makes it possible to clarify the feasibility and importance of performing the treatment on the QoC information in U-learning environment, which was show by a case of study.

Talking about the difficulties, the tests with users helped to identify some limitations regarding the files adaptation according to the cognitive profile, since that in some cases some presented materials were not the users' preferences. So, the limitations correction has to be done so that the environment can adapt itself to the user's preferences in a correct way.

The next step of this work is to the corrections that have already been identified, seeking for new alternatives which can be used in the environment and test it with a more broad users group and in a longer period of time.

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