Adaptive M-Learning

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1. Introduction

M-Learning is a new education's paradigm that is growing in educational institutions in Brazil and worldwide which encompasses the use of mobile technologies with some data processing capacity as cellular phones, PDAs, notebooks, and wireless Internet access enabling students to break the time and space barriers without class schedules and fixed access points; teaching and learning really at any time, really anywhere, even while in movement (Oliveira & Medina, 2007; Mermelsein & Tal, 2005; Trifonova & Ronchetti, 2006; Mcalister & Xie, 2005).

These technologies can access learning objects that include content and evaluation activities in several formats and media. However, not always the obtained objects are the most indicated to the students' learning styles and to a visualization and usability adequate to the mobile devices.

In addition to that, in a situation in which the content of the objects that can be accessed are already known by the student, he or she may become unmotivated by the need of having to study subjects that are already mastered by him or her. Besides, the student's performance is not always taken into consideration to propose new elements of study.

The present learning environments are systems made of: i) tools for administration and management of content, users and courses; ii) synchronous and asynchronous communication tools; iii) tools for evaluations creation and control. Such environments allow the use of learning objects that cannot always be adequately accessed by mobile devices.

Among these environments we may cite: i) Blackboard Learning System, created by the company Blackboard Inc., disseminated worldwide and not free; ii) MOODLE (Modular Object-Oriented Dynamic Learning Environment), free software of learning support that is largely used; iii) CTELCS (Collaborative Training Environment of the Laboratory of Communications and Signals), a learning environment prototype developed at the LCS-EPUSP laboratory (Oliveira, 2003); the collaborative environment of the TIDIA Ae project (*Tecnologia da Informação no Desenvolvimento da Internet Avançada – Aprendizado Eletrônico*; Information Technology in the Development of the Advanced Internet - Electronic Learning) developed by research laboratories and funded by FAPESP (*Fundação de Amparo à Pesquisa do Estado de São Paulo*), that helps the electronic learning activities, offering support for presencial teaching (Tidia Ae, 2009); and many others.

Presently there are several efforts targeting the development of systems and learning objects that allow the access and visualization by mobile devices in an adequate way.
When the learning environments provide access to content by means of mobile devices, enabling the M-Learning, they allow the access to learning objects, but they do not take into account the technology's characteristics, the learning styles, the students' pre-acquired knowledge and performance.
This chapter presents the proposal of a software architecture to be used for content management that allows to provide learning on mobile platforms considering:

- the selection of learning objects that are best adapted to: i) the mobile device's technological data; ii) learning style information; iii) student's performance; iv) acquired knowledge of the student; v) content associated to a course;
- that the teacher and the student may inform some characteristics of their preference concerning a learning object;
- the interaction of the student with the mobile device and the learning object as well.

The architecture has been elaborated in modules: some modules on the server, a module responsible for the management of learning objects and three modules for the mobile device aiming to provide adaptation.
The modules proposed for the server are:

- the technology module that is in charge of receiving some data concerning the mobile device;
- the student's performance module that is responsible for manipulating the data concerning the students' performance in the proposed activities and content;
- the knowledge module performs the manipulation of the students' pre-acquired knowledge and the acquired knowledge during the students interaction with the activities and content of the on-going course;
- the student's learning styles module that manipulates the data concerning the students' learning styles independently of the enrolled course;
- the adaptation module, that is the focus of the adaptive M-Learning architecture, where the data received from the other modules are processed to determine the adequate content and adapted to the students and mobile devices characteristics;
- the content module that is charge of retrieving the learning object that has characteristics found by the adaptation module.

We can think about this software architecture proposal as part of a learning environment that can also be coupled to an existing environment.
It is worth to emphasize that despite the adaptability treatment is targeted towards mobile devices, due to the generic character of the architecture that performs the adaptation, it can also be directed to non mobile computers.
It is also important to inform that, as an assumption, in real situations the student does not perform the study or all activities of a given course only on mobile devices. Usually, the student employs the mobile device to access content or to perform activities in some stages of his/her study.
This chapter has been organized in sections according to the following description. Section 2 makes a brief summary of related work. Section 3 describes the fundamental concepts related to this chapter's theme. The adaptive M-Learning architecture is depicted in Section 4. Section 5 discusses possible techniques for implementing an algorithm that makes it possible the adaptation of learning objects. Section 6 presents an example of how the

Adaptive M-Leraning works. At last, Section 7 discusses the characteristics of the designed architecture, the needed research to make it complete and summarizes the conclusions.

2. Related Works

Some works along this research line around the world are:

- The KOD "Knowledge on Demand" Project, comprehending the laboratories CERTH-ITI from Greece, FD Learning from England, GIUNTI Interactive Labs from Italy and CATAI from Spain, defines the specification of an e-learning architecture that provides adaptive and reusable content (Sampson et al, 2002);
- MAS-PLANG (MultiAgent System-PLAtaforma de Nueva Generation) Project, that has been developed at the University of Girona in Spain, is an intelligent adaptive tutoring system which uses multi-agents systems with the objective of selecting instructional material for the student in a customized way based on his/her learning style and current knowledge (Peña et al, 2002);
- JADE (Java Agent framework for Distance learning Environments), offers a set of resources that make it easier the development and implementation of computational environments to be used as distance learning instruments. The agents, that don't have mobility, are: Contents Managers, Exercises, Examples, Interactions, Student Model and Communication (Silveira & Vicari, 2002);
- The AdaptWeb (Adaptive Web) project that studies adaptive hypermedia systems for distance learning via web, mainly adaptive interfaces (Musa & Oliveira, 2004);
- BAGHERA is a distance learning platform that has an interface for solving geometry demonstration problems. In the development a multi-agent system has been used made of non-humane agents that interact among themselves according to their competences, cooperating and collectively performing educative tasks. In the environment, each learner has three kinds of agents: Learning Agent Companion, Mediator and Tutor. Similarly, the teacher has two kinds of agents: Teaching Companion and Assistant (Pesty & Webber, 2004);
- ALLEGRO is an intelligent environment made of an intelligent tutoring system that offers individualized apprenticeship and a CSCL (Computer-Supported Collaborative Learning) that enables collaborative learning. The environment has been modeled as a MAS (Multi-agent System) that offers: autonomy, flexibility and adaptability (Vicari et al, 2007);
- MACES (Multi-agent Architecture for a Collaborative Educational System) is a multi-agent collaborative learning system for distance learning. Its architecture is made of human agents (Learners and Tutors) and by five types of artificial agents, namely: Diagnostic, Mediator, Collaborative, Social and Semiotic (Kown et al, 2007);
- AMPLIA (Intelligent Probabilistic Multi-Agent Learning Environment) is an environment that has been designed as an additional resource for medical students formation. Its users (learners, teachers and applications) are represented by autonomous agents that belong to a social network based on objectives that communicate, cooperate and negotiate. It has the following artificial agents: Learners, Domain and Mediator (Vicari et al, 2008);
- Content Adaptation in Mobile Multimedia Systems for M-Learning of the Bucharest Academy of Economic Studies in Romania (Revieu et al., 2008).

- TIDIA Ae (*Tecnologia da Informação no Desenvolvimento da Internet Avançada – Aprendizado Eletrônico*; Information Technology in the Development of the Advanced Internet - Electronic Learning) helps in learning activities, offering support to presential teaching and makes it possible to the user to keep a personal profile, a shared calendar, interact with teachers and students, perform tests, make available and share instructional resources (Tidia Ae, 2009);

3. Fundamental Concepts

The conceptual map, illustrated in Figure 1, presents the several concepts related to Adaptive M-Learning (Tavares & Luna, 2003).
In the map, the concepts are represented according to scheme described in Table 1.

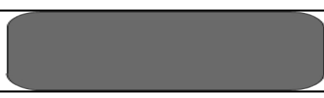
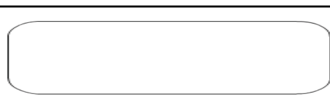
Color scheme	Concept
	focus concept, i. e., Adaptive M-Learning
	driving and motivating concepts of the research about Adaptive M-Learning
	fundamental concepts. These subjects are the necessary knowledge for the Adaptive M-Learning elaboration
	relevant concepts, but not fundamental. These concepts will surely be used as a foundation or basis of other concept and to provide examples in practical situations
	conceptually important, but not relevant for the focus

Table 1. Conceptual map scheme.

According to the conceptual map, me may list as fundamental concepts: mobile technologies, learning objects, learning styles, student's pre-acquired knowledge and student's performance.
The knowledge of these concepts if of paramount importance so that the adaptive M-Learning architecture can be designed.

3.1 Mobile Technologies

Mobile technologies comprehend devices as the cellular phone, PDA and smartphone, that are used in the teaching and learning process to access instructional content anytime and anywhere, profiting by free time while waiting in a line or during displacement on a means of transport.
Notwithstanding, despite of the advantages of mobility it is necessary to point out the limitations of these devices as far as hardware and software resources are concerned, as: processing power, screen size, quantity of memory, typing difficulty, user expectation and functional limitations of the operating system of each device (Oliveira & Medina, 2007).

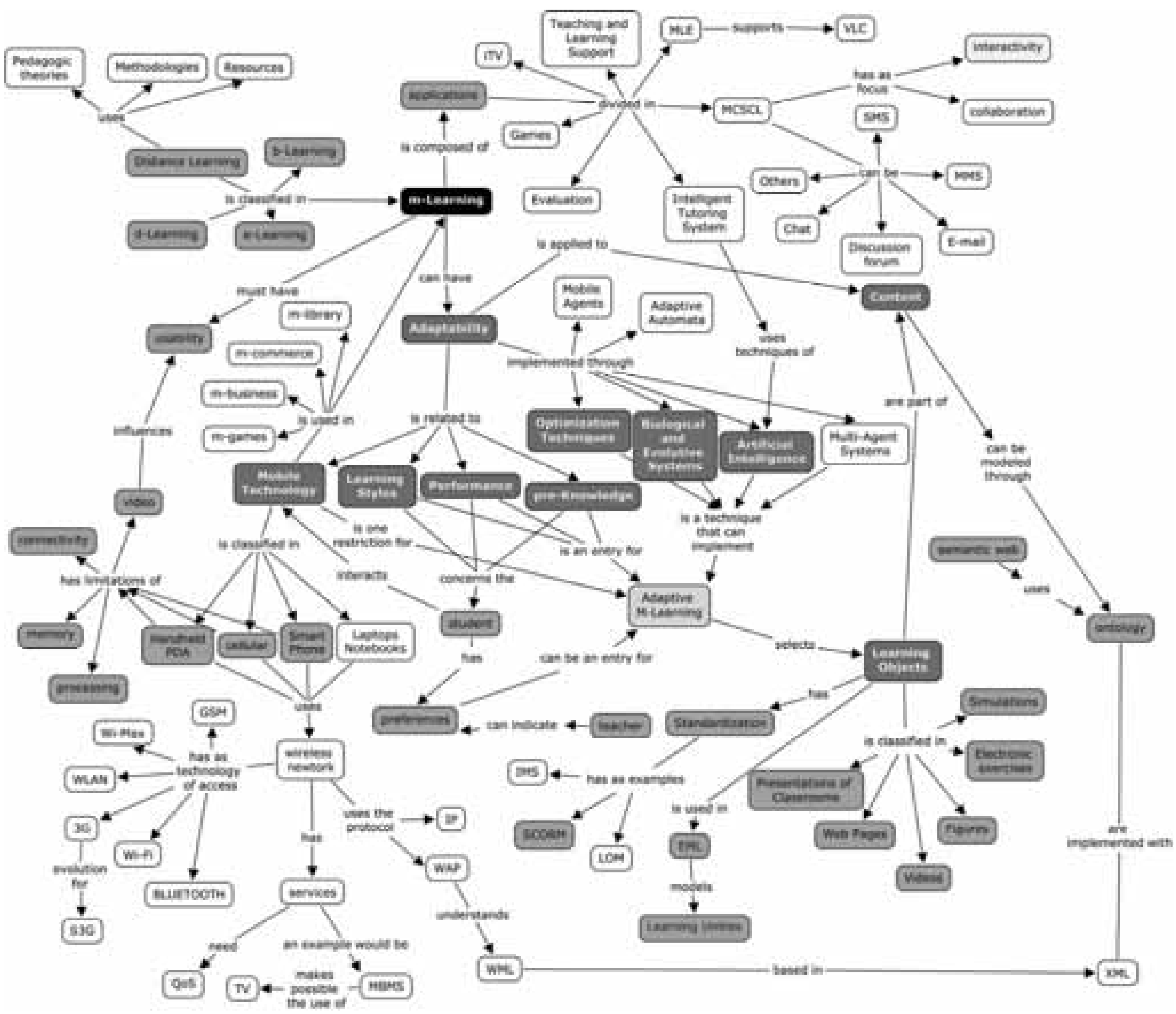


Fig. 1. Concepts related to Adaptive M-Learning.

3.2 Learning Objects

The term learning objects refers to any resource, digital or not digital, that can be used and reused for supporting the apprenticeship (Oliveira et al., 2003).

Some examples of learning objects are: web pages, images, audio resources, Flash animations, Powerpoint presentations, a game, a pdf text, a self-correcting electronic evaluation, etc.

To make the interoperability easier, or even possible, the learning objects must be standardized. Among the possible standards, in this chapter the learning objects descriptions are based on SCORM (Shareable Content Object Reference Model) (Scorm, 2004).

The SCORM is an unified set of specifications to make available e-learning contents and services. This set of specifications defines a model of content aggregation, a model of sequencing and an execution environment for learning objects (Scorm, 2004). It is important to emphasize that despite of having been planned for e-learning the SCORM fits to be used in M-Learning.

In SCORM, an object/resource is associated to metadata that allow to catalogue it and, then, look for and find it in online repositories.
One differential concerning the use of SCORM for the content development for distance learning courses is its focus on reusability, interoperability, accessibility and durability.

3.3 Learning Styles

Learning styles are defined, according to (Felder & Silverman, 1988), as a characteristic and prevailing preference concerning the way people receive and process information, considering the styles also as skills that may be developed.
There are several models that deal with this subject and among them we may cite:

- The Myers-Briggs Type Indicator (MBTI) (Myers & McCaulley, 1985);
- Kolb's Learning Style Model (Kolb, 1983);
- Herrmann Brain Dominance Instrument (HBDI) (Hermann, 1990);
- Felder-Silverman Learning Style Model (FSLSM) (Felder & Silverman, 1988).

We adopted the FSLSM model because it has already been used in the development of adaptive applications (Peña et at., 2002).
According to the FSLSM model the learning process has the following dimensions: processing (active/reflexive), perception (sensorial/intuitive), input (visual/verbal) and understanding (sequential/global).
The learning styles initial data may be obtained by means of a diagnostic tool, named ILS (Index of Learning Styles), that has a questionnaire with 44 items.
Some examples of the ILS' questions are illustrated in Table 2.

Question	**Alternatives**
I understand better after	experimenting.
	thinking about.
As entertainment, I prefer to	watch TV.
	read a book.
The idea of working in groups, with a grade for the whole group,	appeals me.
	does not appeal me.

Table 2. Examples of ILS' questions.

After carrying out the ILS test, the initial learning style is presented as shown in Figure 2.
According to Figure 2, if the student is between:

- 1-3 he/she is relatively well balanced on both scale dimensions;
- 5-7 he/she has a moderate preference for one scale dimension and will learn more easily if the educational environment favors this dimension;
- 9-11 he/she has a strong preference for one scale dimension, indicating that he/she may have real difficulties learning in an environment that does not support this preference.

3.4 Pre-acquired Knowledge

The pre-acquired knowledge of a subject or course refers to the contents that are mastered by the student. They can be obtained by applying a questionnaire with the objective of identifying what is already known by the student.

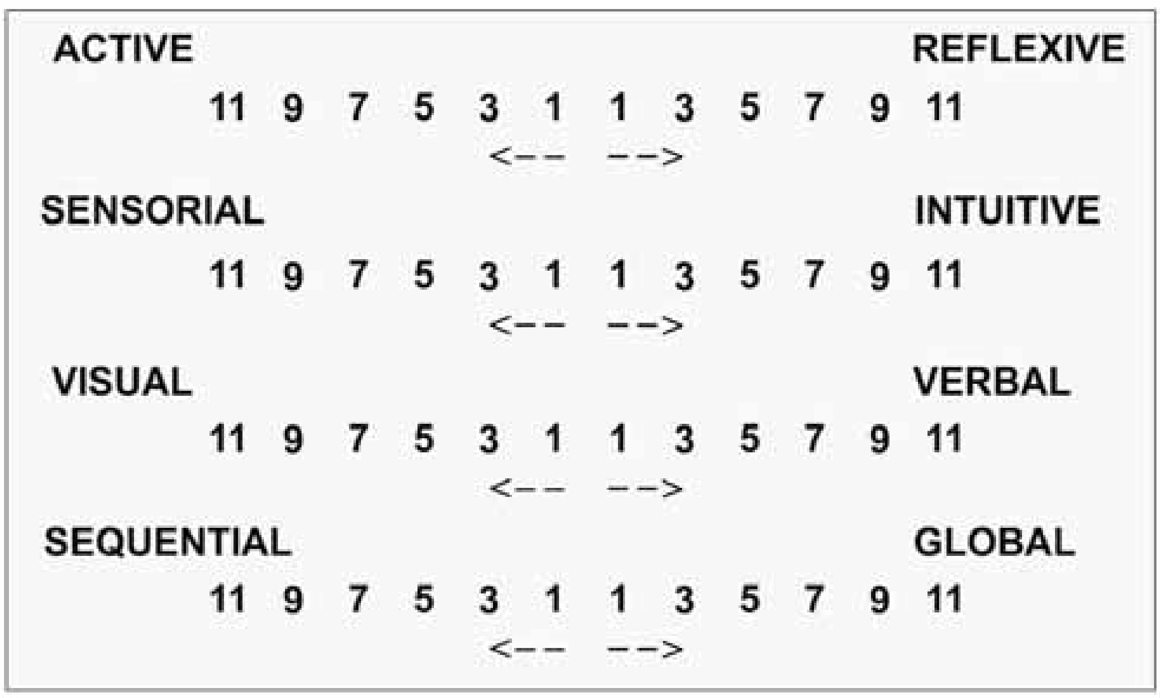


Fig. 2. Obtained result by applying the ILS diagnostic tool.

3.5 Student's Performance

The term performance is related to the result achieved by the students in a given subject when they are evaluated or by the time they stay on a given topic under study. From these measurements, it is possible to estimate the student's performance and identify if it is necessary to reinforce any topic that has not been well learned yet (Amazonas, 2005).

4. Adaptive M-Learning: proposal of an archictecture

The adaptive M-Learning architecture, presented in Figure 3, has the following elements:

- Learner´s Side: represented by the mobile technology and by the student interaction with the content and interface;
- Content Server´s Side: made of modules that manipulate the mobile device's, the student's and the course's characteristics aiming at providing adaptability of the learning objects;
- Teacher´s Side: is in charge of manipulating the learning objects, the information that describe them, and the adaptation rules provided by the teacher.

It is important to emphasize that the architecture shown in Figure 3 presents the elements that manipulate the data which are necessary to provide the content adaptability. However, a complete educational system should include other elements, as for example: users and courses administration; synchronous and asynchronous collaboration tools; and system configuration tools.

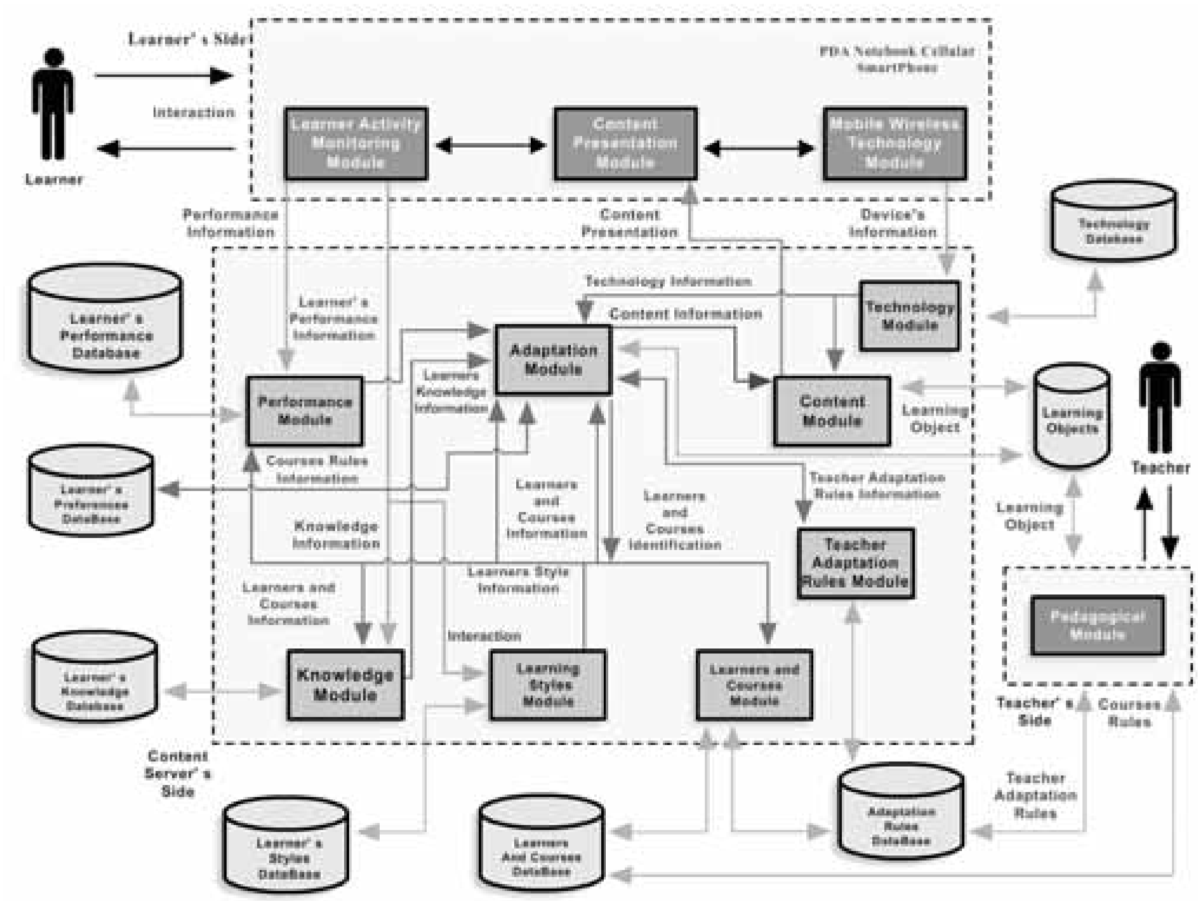


Fig. 3. Adaptive M-Learning architecture.

4.1 Learner's Side

The Learner's Side is represented by the mobile device, the content's presentation interface and by the interaction of the student with both the device and the content as well.

The Learner's Side modules are:

- Mobile Wireless Technology: this model gets information about the mobile devices as type of device (PDA, smartphone, etc.) and device's model;
- Learner Activity Monitoring: this model is in charge of monitoring the student's interaction with the content and the mobile device getting information about the interactions performed with the device, the interface and the learning object; the interaction time with the learning object; the idle time, i. e., the time interval the student has not performed any investigative action while staying at a given interface; the student's performance with the proposed activities;
- Content Presentation: interface presented to the student on the mobile device containing the learning object that has been selected according to the following parameters: learning styles, information about the mobile device, data about the

student's performance, interactions performed by the student both on the interface and device, and pre-acquired knowledge.

The initial students' preferences for types of specific objects, their initial learning style and pre-acquired knowledge, can also be obtained by means of the mobile device. However, it is worth to point out that a device with a screen that can show a larger quantity of content may be more adequate to get these initial values.

4.2 Teacher's Side

The Teacher's Side is made of the Pedagogical Module. This module is used to insert the learning objects and their respective information in a repository of objects and contents.

The information concerning the learning objects are coded according to the SCORM standard. Briefly, some of these information are: general data that describe the object; the characteristics related to the object's historic; its current state and all elements involved in its evolution; the object's requirements and technical characteristics; the object's educational and pedagogical characteristics.

These information and objects are obtained from teachers in the content and/or from developers of the learning objects.

In addition to these information, this module allows to insert and to obtain the adaptation rules that the teacher wants to apply to his/her course and to provide them to the adaptation module.

The data obtained from this module are essential to the adequate selection of the learning object, according to the adaptation parameters.

4.3 Content Server's Side

The Content Server's Side is responsible for:

- receiving information about the students' current knowledge, learning style and the mobile device's characteristics;
- storing the acquired knowledge, performance, interactions and learning styles in specific databases;
- manipulating the received information to enable the adaptation of the objects to the student's preferences and the device's characteristics, according to the course's adaptation rules provided by the teacher;
- send the adapted content to the client student.

The Content Server's Side is made of several modules that are described in the following sub-sections.

4.3.1 Techology Module

The Technology Module is the module that is in charge of receiving some data about the mobile device, as type and model, that make it possible to retrieve information about the device from the Technology Database, as illustrated in Figure 4. Using this information, it is possible to perform the device-based adaptation.

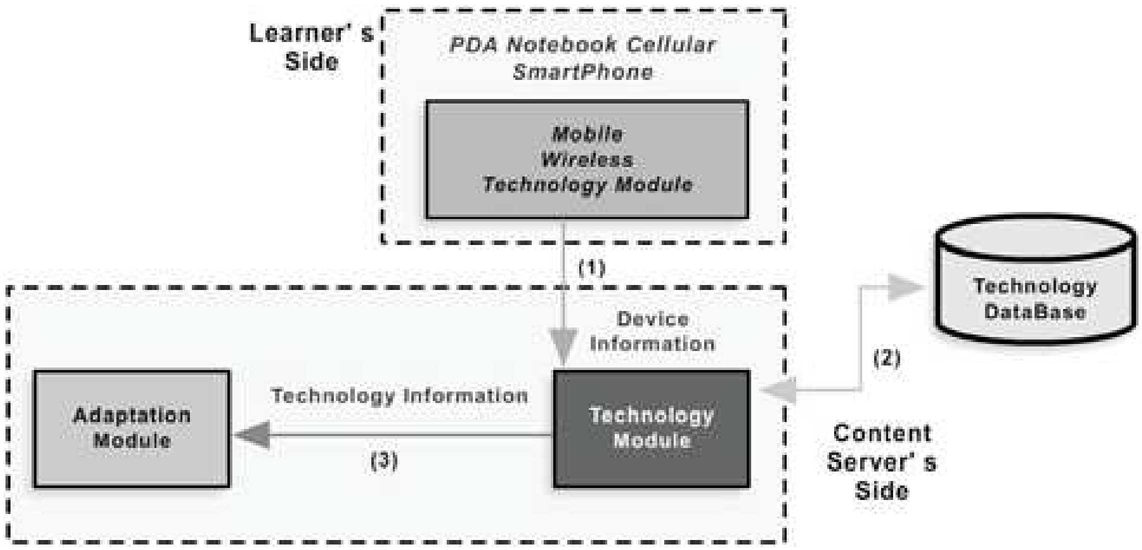


Fig. 4. Technology Module.

From Figure 4, we can verify that the message **Device Information (1)** is received by the Technology Module, that, by its turn, receives the message **Technology Information (2)** from the Technology Database and forwards it to the Adaptation Module **(3)**. The Adaptation Module is in charge of performing the adaptation to the device. The format of these messages is as follows:

- **Device Information** comprised of d = [d1, d2], where:
  - d1: Device type: PDA, notebook, cellular, smartPhone;
  - d2: Device model: LG Shine SLIM ME770d, Sansung Light CAM, among others.
- **Technology Information** comprised of t = [t1, t2, t3, t4, t5, t6, t7], where:
  - t1: Transmission rate: number of bytes/second;
  - t2: Keyboard type: numerical, alphanumerical;
  - t3: Screen size: y bytes horizontal x z bytes vertical;
  - t4: Type of access/technology: Bluetooth, GSM, WAP;
  - t5: Operating system;
  - t6: Quantity of memory: number of bytes;
  - t7: Extra functions.

4.3.2 Performance Module

The Performance Module manipulates the data concerning the students' performance in the proposed activities and contents, as shown in Figure 5.

The performance data, named **Performance Information (1)**, are obtained by means of the achieved results in the activities performed by the student and/or by the time he/she has taken to complete a given content or activity of each course in which he/she is enrolled.

The Performance Module receives the message **Performance Information (1)**; gets the list of objects/performance manipulated by the student related to his/her course and content from the Learner's Performance Database **(3)**; requests and receives the rules of the programmatic content under study, named **Courses Rules Information (2)**; and mounts the message about the student's performance, named **Learner Performance Information (4)** and forwards it to the Adaptation Module.

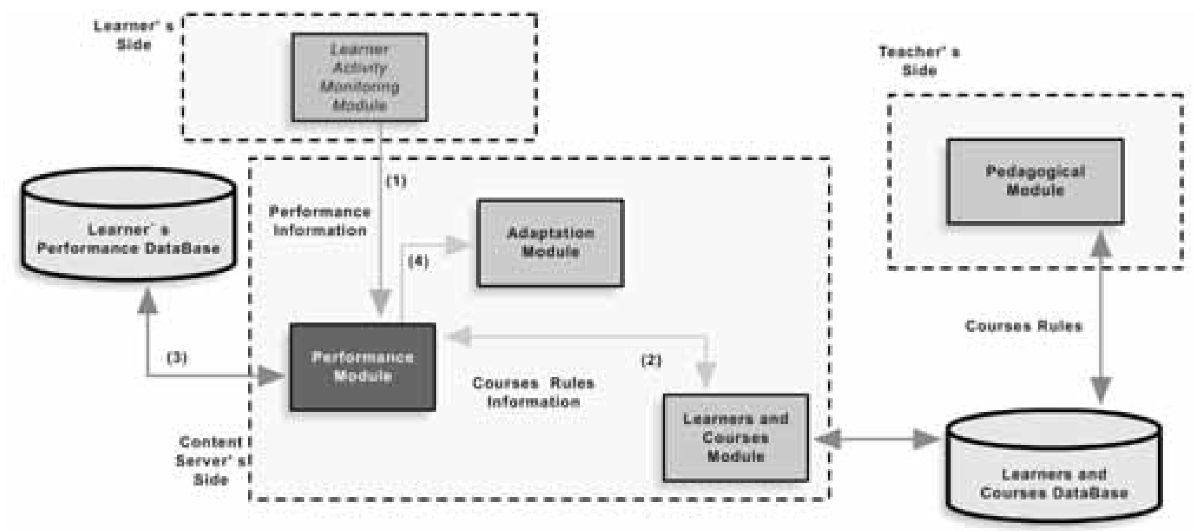


Fig. 5. Performance Module.

The format of the messages exchanged by the Performance Module are:

- **Performance Information** comprised of p = [p1, p2, p3, p4, p5, p6], where:
  p1: learner identification;
  p2: course identification;
  p3: content identification;
  p4: type of content, learning object as element of study (e) or as activity/evaluation (a) or collaborative tool (Forum, chat,...) (fc);
  p5: if p4 is equal to (e), p5 represents the time spent in the activity in seconds; if p4 is equal to (a), p5 represents the result achieved in the activity; if p4 is equal to (fc), p5 represents an account of the student participation in a collaborative activity that is not a learning object;
  p6: current object identification;
- **Courses Rules Information** comprised of c = [c1, c2], where:
  c1: course identification;
  c2: course's programmatic content containing an ordered list locp = (locp1, ..., locpn), where each locpi is comprised by the set [content identification, content type, keywords, performance or timing or participation]. It is important to observe that keywords = [k1, k2, ..., km], where m is the number of words that identify the subject.
- **Learner Performance Information** comprised of lp = [lp1, lp2, lp3, lp4, lp5 , lp6, lp7], where:
  lp1: learner identification;
  lp2: course identification;
  lp3: content identification;
  lp4: type of content identification to be selected, that can be: collaborative activity (Forum, chat, ...) (fc), learning object as element of study (e), or activity/evaluation (a);

lp5: list of object identification and type, related to the content identification, already selected/performed lpoi = [lpoi1, ..., lpoin];
lp6: if lp4 is equal to (e), lp6 represents the time spent in the activity in seconds; if lp4 is equal to (a), lp6 represents the result achieved in the activity; if lp4 is equal to (fc), lp6 represents an account of the student participation in a collaborative activity that is not a learning object;
lp7: current object identification;

4.3.3 Knowledge Module

The Knowledge Module performs the manipulation of the student's pre-acquired knowledge and of the knowledge acquired by his/her interaction with the contents/activities of an on-going course. This module is illustrated in Figure 6.

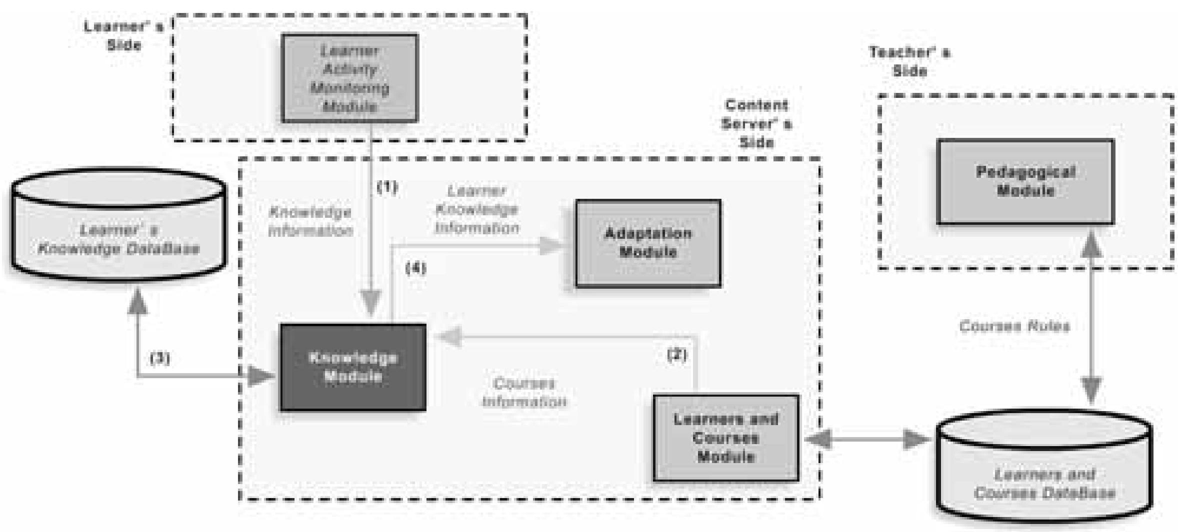


Fig. 6. Knowledge Module.

With the obtained by this module it is possible to identify what a student knows.
It is important to realize that depending on the pre-acquired knowledge it is possible that a student progresses along the course's content in a non-sequential way.
The data about the content manipulated by the student by his/her interaction with the learning object (message **Interaction Knowledge (1)**) is received by the Knowledge Module that gets information about the course (message **Courses Information (2)**) and about the subjects the student knows, from the Learner´s Knowledge DataBase **(3)**. The Knowledge Module prepares the **Learner Knowledge Information (4)** and forwards it to the Adaptation Module.
From Figure 6, we identify:

- **Interaction Knowledge** comprised of ik = [ik1, ik2, ik3, ik4], where:
  ik1: learner identification;
  ik2: course identification;
  ik3: content identification;
  ik4: interaction information.
- **Courses Information** comprised of ci = [ci1, ci2], where:
  ci1: course identification;

ci2: course's programmatic content containing an ordered list locp = (locp1, ..., locpn), where each locpi is comprised by the set [content identification, content type, keywords, performance or timing or participation]. It is important to observe that keywords = [k1, k2, ..., km], where m is the number of words that identify the subject.

- **Learner Knowledge Information,** based on the information about pre-known items of content, the course's programmatic content and the interaction with the current content, lki = [lki1, lki2, lki3, lki4] is generated, where:
  lki1: learner identification;
  lki2: course identification;
  lki3: next content identification to be selected;
  lki4: next type of content identification that can be a learning object as element of study (e), or activity/evaluation to be selected (a), or collaborative activity (fc) to be performed.

4.3.4 Learning Styles Module

The Learning Styles Module, illustrated in Figure 7, manipulates the data concerning the students' learning styles, independently from the course they are enrolled in.
The initial learning styles data are obtained by means of the ILS (Index of Learning Styles) and are stored in the Learner´s Styles DataBase (Felder & Silverman, 1988).

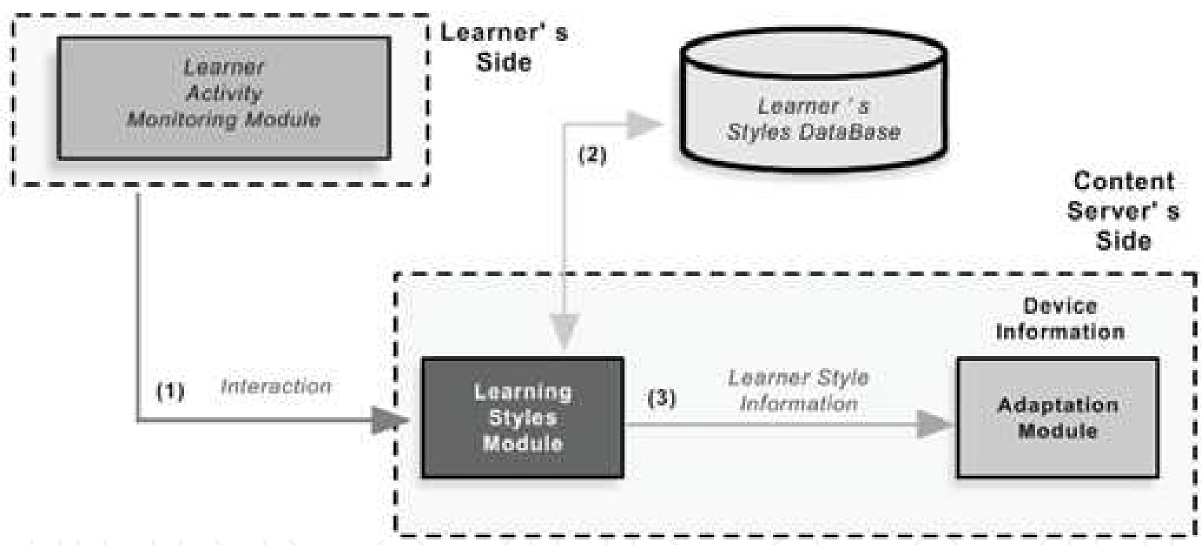


Fig. 7. Learning Styles Module.

The Learning Styles Module receives the information about the student's interactions with the learning object, message **Interaction (1)**, get the current data about the learning style from the Learner's Styles DataBase **(2)**, manipulates these data, modifying, if it is necessary, the student's learning style. Then, it stores the learning style in the Learner's Styles DataBase and sends the message **Learner Style Information (3)** to the Adaptation Module.
It is important to observe that by querying the Learner's Style DataBase about the object manipulation and current learning style, it is possible to track the style modifications.
From Figure 7, we observe:

- **Interaction** is comprised of i = [i1, i2, i3], where:
  i1: learner identification;
  i2: object identification.
  i3: interaction information.
- **Leaner Style Information** is comprised of lsi = [lsi1, lsi2, lsi3, lsi4, lsi5], where:
  lsi1: learner identification;
  lsi2: value in the input dimension: 0 – visual, 1 – oral/verbal, 2 – don't care;
  lsi3: value in the perception dimension: 0 – sensorial, 1 – intuitive, 2 – don't care;
  lsi4: value in the understanding dimension: 0 – sequential, 1 – global, 2 – don't care;
  lsi5: value in the organization dimension: 0 – inductive, 1 – deductive, 2 – don't care.

4.3.5 Learners and Courses Module

This module is responsible for obtaining the data related to a course's programmatic content, the rules of expected performance in the subjects, the items of content and the activities.
It is by means of these data that it is possible to verify what are the next contents to be studied by a student. This module is illustrated in Figure 8.
It is important to point out that the storage and organization of data in the Learners and Courses DataBase is done by a courses and students management module that is not part of this architecture.

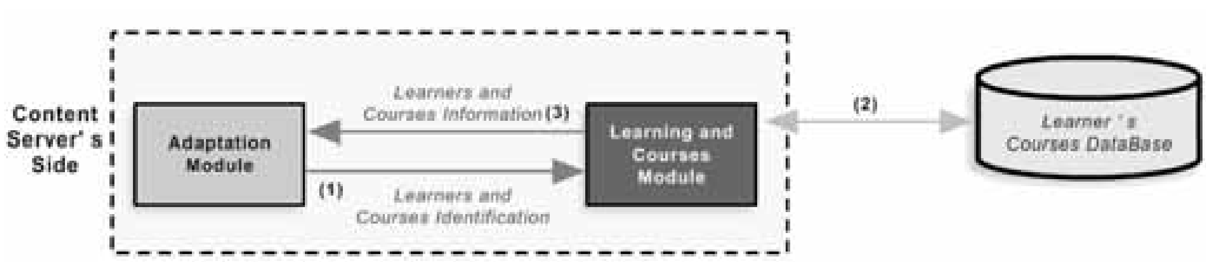


Fig. 8. Learners and Courses Module.

The Adaptation Module requests to the Learners and Courses Module the programmatic content of an on-going course by means of the message **Learners and Courses Identification (1)**. The Learners and Courses Module retrieves the data from the Learners and Courses DataBase **(2)** and send them to the Adaptation Module in a return **Learners and Courses Information (3)** message.
The formats of the messages are:

- **Leaner and Courses Identification** comprised of lci = [lci1, lci2], where:
  i1: learner identification;
  i2: course identification.
- **Leaner and Courses Information** comprised of lcinf = [lcinf1, lcinf2], where:
  lcinfi1: course identification;
  lcinfi2: course's programmatic content containing an ordered list locp = (locp1, ..., locpn), where each locpi is comprised by the set [content identification, content type, keywords, performance or timing or participation]. It is important to observe

that keywords = [k1, k2, ..., km], where m is the number of words that identify the subject.

4.3.6 Content Module

The Content Module, illustrated in Figure 9, is in charge of:

- retrieving the learning object that has its characteristics best adapted to the student and to the device;
- mounting an interface to be displayed on the device;
- forwarding the interface to the device.

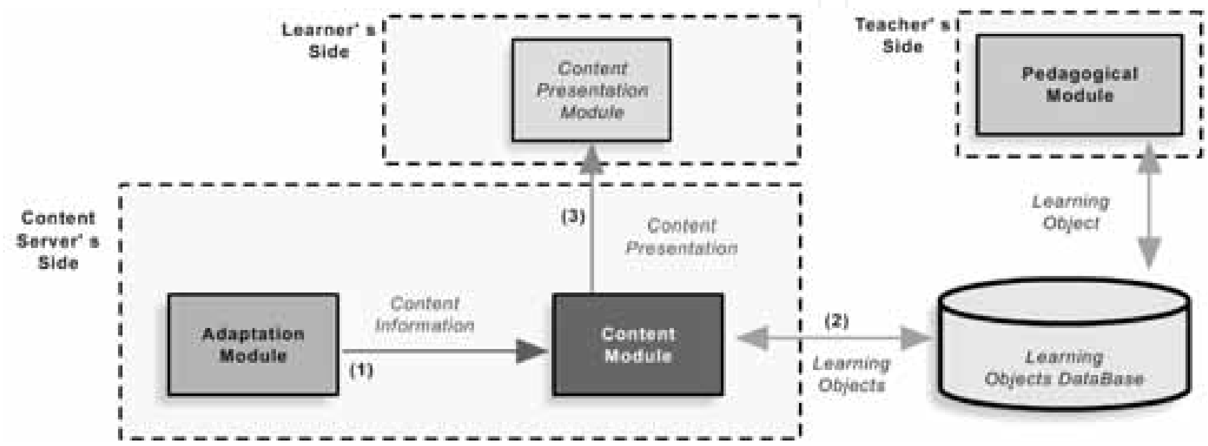


Fig. 9. Content Module.

The Content Module receives the message **Content Information (1)** from the Adaptation Module. This message carries: the course's, student's identification; the candidate learning objects; data about the mobile device. The Content Module selects one of the candidates learning objects **(2)**, stores the identification of the selected object, gets characteristics of the mobile device's interface, mounts the message **Content Presentation (3)** and sends it to the Content Presentation Module running on the mobile device.

From Figure 9, we have:

- **Content Information** comprised of ic = [ic1, ic2, iclo, icd1, icd2], where:
  ic1: learner identification;
  ic2: course identification;
  iclo: candidate learning objects in the form of a list (lo1, ..., lon). All these objects comply with the student's and the device's adaptation rules;
  icd1: device type: PDA, notebook, cellular, smartPhone;
  icd2: device model: LG Shine SLIM ME770d, Sansung Light CAM, among others.
- **Content Presentation** is the message with the interface that contains the learning object to be displayed on the mobile device.

4.3.7 Teacher Adaptation Rules Module

This module gets the adaptation rules from the Adaptation Rules DataBase **(2)**, inserted by teacher in his/her course, in response to the Adaptation Module request and sends them as the message **Teacher Adaptation Rules Information (1) (3)**.

The message **Teacher Adaptation Rules Information** allows the teacher to indicate what are the media that can be presented to the student and enables the configuration of the types of adaptation as well.
This module is illustrated in Figure 10.
From Figure 10 we have:

- **Teacher Adaptation Rules Information** comprised of tari = [tari1, tari2, tari3, tari4, tari5, tari6], where:
  tari1: course identification;
  tari2: list of media to be displayed, as for example: video, text/hypertext/hypermidia, audio, simulation, animation;
  tari3: performance adaptation, 0 – present, 1- missing;
  tari4: knowledge adaptation, 0 – present, 1- missing;
  tari5: learning styles adaptation, 0 – present, 1- missing;
  tari6: technology adaptation, 0 – present, 1- missing;

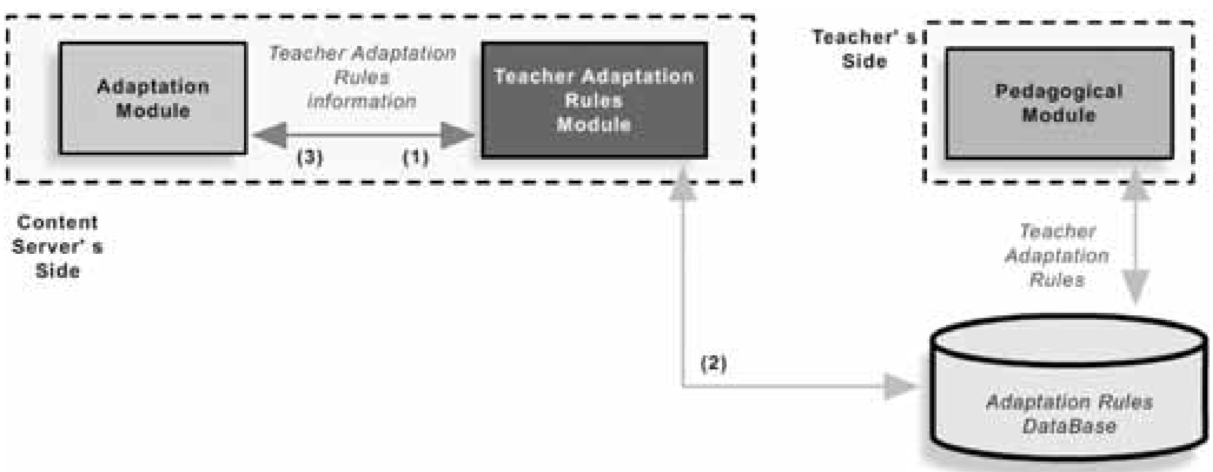


Fig. 10. Teacher Adaptation Rules Module.

4.3.8 Adaptation Module

The Adaptation Module is the central module of the adaptive M-Learning architecture. It receives the messages from the other modules **(1)**, gets the list of learning objects **(2)**, process them to find out which learning objects are adequate and adaptive to the student's and the mobile device's characteristics. Then, it prepares the message with the selected learning objects (**Content Information (3)**) and sends it to the Content Module.
The messages received and generated by the Adaptation Module have already been described in the previous sub-sections.
In Figure 11 we observe that, besides the messages received from the other modules, there is the **Teacher Adaptation Rules Information** containing the adaptation rules provided by the teacher and the types of media preferences informed by the student, in the case he has indicated any, obtained from the Learner Preference DataBase.

5. Adaptation Algorithm: Possible Techniques

In this section we will briefly explain some optimization and computing intelligence techniques to evaluate and verify the possibility of using them in the development of an algorithm responsible for the adaptation implementation.
The algorithm works inside the Adaptation Module, as illustrated in Figure 11. An algorithm's description, without taking into consideration any specific technique to solve the adaptation, is presented in Figure 12.
On line (d) of the algorithm shown in Figure 12, takes place the manipulation of the messages and input data. To do so, one or more techniques of optimization and/or computing intelligence may be used.

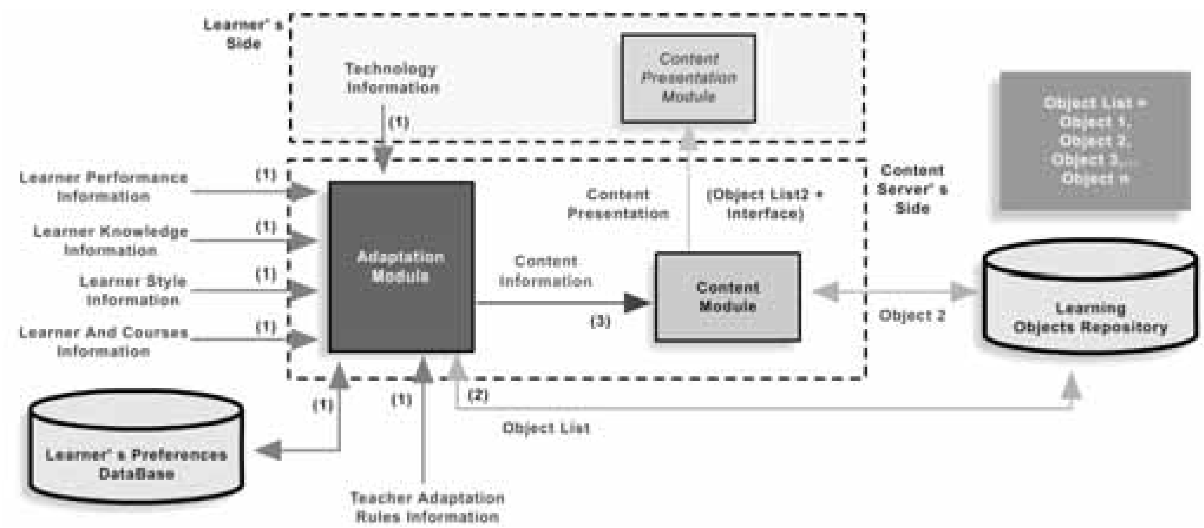


Fig. 11. Adaptation Module.

```
Adaptation Algorithm
Begin
   a) Receive the messages: Technology Information, Learner
      Performance Information, Learner Knowledge
      Information, Learner Style Information, Learner and
      Courses Information, Teacher Adaptation Rules
      Information;
   b) Gets the students' preferences;
   c) Gets the list of learning objects according to the
      SCORM standard;
   d) Processes all messages and data evaluating and
      selecting the most adequate objects;
   e) Mounts the message Content Information;
   f) Sends Content Information to the Content Module;
End.
```

Fig. 12. Description of the Adaptation Algorithm.

In the following sub-sections some of the studied techniques will be cescribed, namely:
1. fuzzy logic;
2. genetic algorithms;
3. ants colony optimization; and
4. graphs theory, more specifically the paths algebra proposed in (Herman, 2008).

5.1 Fuzzy Logic

Fuzzy logic is a non-standard logic elaborated by Lofti A. Zadeh in 1965 with which it is possible to capture imprecise information, described in natural language, and convert them to a numerical format that represent expressions that usually cannot be treated by the classical logic systems (Bittencourt & Osório, 2002; Zadeh, 1965).
The systems that implement fuzzy logic use a set of IF-THEN rules that are based on linguistics variables. Theses variables represent a fuzzy set that vary continuously in a range, named transition, between 0 (totally non-member) and 1 (totally member). The transition is represented by a membership function that outputs a number in the (0, 1) interval.
Shortly, according to (Bittencourt & Osório, 2002), the fuzzy systems should be able to:
1. define fuzzy variables and sets;
2. define IF-THEN rules and logical operators that manipulate fuzzy variables;
3. make inferences using the rules;
4. offer different methods to convert the fuzzy data to numerical values.

In the Adaptive M-Learning, it is possible to visualize some fuzzy variables, as for example:
a)performance: that represents the student's performance related to a learning object of a given activity. It could be defined as A [8.5 , 10] = best, B [7, 8.5] = good, C [5, 7] = regular, D [3, 5] = bad, E [0, 3] = worst. The membership function for variable is illustrated in Figure 13.

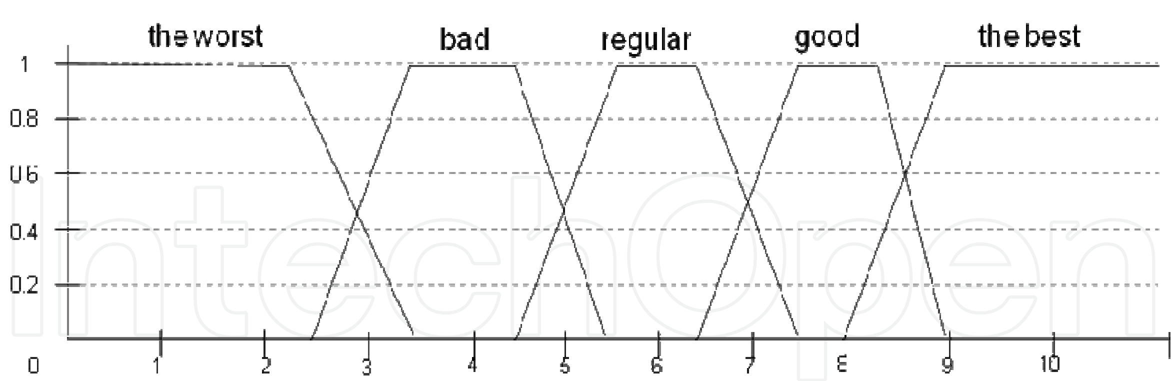


Fig. 13. Membership function for the performance variable.

b) timing: represents the time a student stays studying a learning object of the content type. We may define, for example, short time as a time interval between 0 and 3 minutes, an intermediate time from 3 thru 7 minutes and long time above 7 minutes. The membership function for this situation is illustrated in Figure 14.

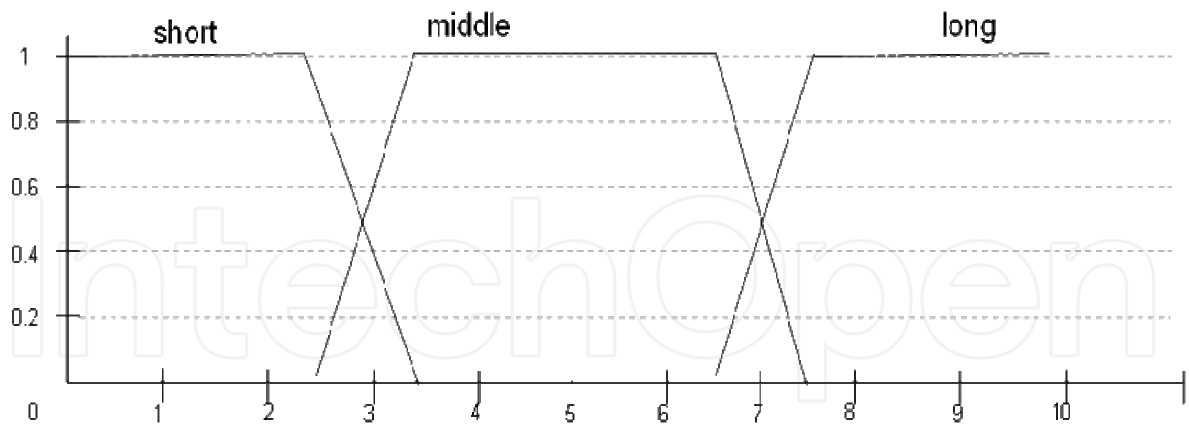


Fig. 14. Membership function for the timing variable.

5.2 Genetic algorithms

The genetic algorithms are a technique of search and optimization based on the Darwinian principle of reproduction and survival of the most apt individuals (Gwiazda, 2006).
These principles are emulated in the construction of computing algorithms that look for the best solution of a given problem, by means of the evolution of population of individuals, coded in artificial chromosomes.
In genetic algorithms, the chromosome is a data structure that represents one of the possible solutions in the problem's search space. The chromosomes are submitted to an evolutionary process made of: inheritance, mutation, selection, and crossover (also called recombination).
After several cycles of evolution the population should be comprised of the most apt individuals. One of the possible stop criteria is the number of generations, represented by the number of evolution cycles.
A basic pseudocode for genetic algorithms is provided in Figure 15.

```
t ← 0;   // indicates the first generation
initialize the population of individuals;
evaluate the fitness of each individual in the population
while a stopping criterium is not satisfied
begin
        Select best-ranking individuals to reproduce
        Breed new generation through crossover and/or mutation (genetic operations) and
give birth to offspring
        Evaluate the individual fitnesses of the offspring
        Replace worst ranked part of population with offspring
        t ← t + 1;  // indicates the next evolved population
end.
```

Fig. 15. Basic pseudocode for Genetic Algorithms.

The Adaptive M-Learning may use this technique to look for the learning objects best adapted to the student's and to the mobile device's characteristics. However, the initialization of the population and the choice of a stopping criterium are complicating elements.

5.3 Ants Colony Optimization

Dorigo and his colleagues (Dorigo & Stützle, 2004) proposed a new multi-agent heuristic approach, named Ant Algorithm, in the beginning of the years 90. They showed that the ants behavior of following a pheromone track deposited by them could be used to solve optimization problems.

The Ant algorithm, that has been originally applied to the travel salesman problem, has been extended and modified by several researchers and then applied to other optimization and search problems.

The Ant Algorithm modifications resulted in the Ant Colony Optimization meta-heuristic.

The basic idea of the Ant Colony Optimization is that a large number of simple and artificial agents are able to build good solutions for hard combinatorial optimization problems by means of low level communications.

If an ant has to choose among different paths, those that were previously the most chosen by other ants, therefore with a high level of pheromone deposited on them, have a higher probability of being chosen again.

The artificial ants are implemented as parallel processes with the objective of building a problem's solution using an algorithm guided by a combination of: artificial pheromone; data of the problem; a heuristic function to decide between its continuation or ending.

The Adaptive M-Learning has to implement a search process with a high degree of complexity, as the learning objects' repository has dynamic characteristics that periodically modify the quantity of objects. However, the Ants Colony Optimization employs simple and artificial elements, the artificial ants, that working together can find good solutions for different kinds of problems (Dorigo & Stützle, 2004).

This technique is highly ranked to be used in the adaptation algorithm, but the determination of what will be used as pheromone is a difficult task.

5.4 Graphs Theory: a New Paths Algebra

In (Herman, 2008) a new paths algebra over directed and weighted graphs has been proposed. It has been used to solve the problems of finding the best path between a pair of source and destination nodes and the convergence of hop-by-hop mono and multi-constraint routing algorithms.

This new algebra defines a mathematical structure (M, F, S, $\leq_{ML}$), where:

- M is a set of routing metrics that, according to an optimization strategy, can represent any attribute or characteristic to be analyzed to choose the best path in a network;
- F is a set of metrics combination functions;
- S is a set of binary operations, i. e., an operation between two elements, that are applied to the value of the combined metrics along a path; and
- $\leq_{ML}$ is a multi-dimensional lexical ordering relation used to order the different existing paths between two nodes in a network.

The new paths algebra can be applied to solve some important problems, as for example, the problem of finding the best path as function of the physical impairments in a DWDM (Dense Wavelength Division Multiplexing) optical network, with automatic configuration of wavelengths and power adjustment, in which the power adjustment is limited by the specifications of the network's transmitters and receivers.

The implementation of the adaptation algorithm for the Adaptive M-Learning can be described as a problem of search of learning objects that are most adequate to the student's and to mobile device's characteristics. It is possible to model the problem as a directed weighted graph in which we want to find the best paths. According to this approach, the new paths algebra may be an interesting alternative.

6. Example of a Typical Situation

Assume that a Computer Science student traveling by bus during two hours decided to study the subject "Stack", related to the "Data Structures" course. To do so, he/she will use his/her cellular phone, model "LG Shine SLIM ME770d", that has the flash liteTM 2.0 installed, has 110 MB of memory available and can visualize documents in PDF and PPT. In addition to that, also assume that there are three objects in the Learning Objetcs Repository concerning the subject "Stack", stored according to the SCORM 1.2 standard (Scorm, 2004) and that can be accessed by this cellular phone model, as illustrated in Table 3.

ADL SCORM 1.2		Objects		
Number	**Name**	**Object 1**	**Object 2**	**Object 3**
1.0	General			
1.2	Title	Stack	Stack	Stack
1.6	Keywords	Stack, Push, Pop	Stack, Push, Pop	Stack, Push, Pop
4.0	Technical			
4.1	Format	ppt	flash lite	pdf
4.2	Size	102400	97280	51200
4.4	Requirement			
4.4.1	Type	Operating System	Browser	Operating System
4.4.2	Name	MS-Windows	Internet Explorer	Multi-OS
4.4.6	Other Platform Requirements	Powerpoint viewer, min 100MB memory	Player Flash Lite^{TM} 2, min 100MB memory	Acrobat reader, min 50MB memory
4.4.7	Duration	PT	PT 0h:30m	PT
5.0	Educational			
5.1	Interactivity Type	Mixed	Active	Expositive
5.2	Learning Resource Type	Slide	Simulation	Lecture
5.3	Interactivity Level	Medium	Very high	Very low
5.5	Intended End User Role	Learner	Learner	Learner
5.8	Difficulty	Easy	Very easy	Medium
5.9	Typical Learning Time	PT1h:55m	PT1h:20m	PT2h:40m
5.11	Language	PT	PT	PT

Table 3. Part of the ADL SCORM 1.2 metadata for three examples of learning objects about the subject "Stack".

Consider that the following data have been sent to the Adaptation Module:

- Technology Module's **Technology Information**: t = [100, alphanumerical, 176x220, WAP GPRS USB Bluetooth, Windows Mobile 5.0, 112640, Flash Java Vídeo MMS SMS];
- Performance Module's **Learner Performance Information**: lp = [ST_01, CCP_DS, Stack, e, [ ], e, 0];
- Knowledge Module's **Learner Knowledge Information**: lki = [ST_01, CCP_DS, Stack, e];
- Learning Styles Module's **Learner Style Information**: lsi = [ST_01, 0, 2, 1, 1];
- Learner and Courses Module's **Learner and Courses Information**: lcinf = [CCP_DS, (…, [Stack, e, [Stack, Push, Pop, Data Structure], PT3h:00m], …)];
- Teacher Adaptation Rules Module's **Teacher Adaptation Rules Information**: tari = [CCP_DS, ANY, 1, 1, 1, 1].

Considering that the teacher has allowed access to the content by means of any type of media (informed by the Teacher Adaptation Rules Information), due to the characteristics of the mobile device (informed by the Technology Information) and, according to Fig. 11, given the availability of n objects (Object List = object 1, object 2,... , object n) in the repository, the Technology Adaptation would select the (object 1, object 2 and object 3) objects of Table 3.
If we consider the student's learning style/knowledge/performance (**Learner Performance Information**, **Learner Knowledge Information**, **Learner Style Information** and **Learner and Courses Information**) and the adaptation rules provided by the teacher (**Teacher Adaptation Rules Information**), and that the student has not any specific preference as midia and format are concerned, the object 2 would be selected (**Content Information**), because it is the only one that meets all requirements..

7. Discussion and Conclusions

In this chapter, it has been presented a proposal of a M-Learning environment where it is possible to identify three blocks in its architecture, namely: the student's and mobile device's; the server that is responsible for the learning objects adaptation; the teacher's.
This architecture comprises several modules and deals with aspects as mobile device technology, pre-acquired knowledge, learning style and student's performance. It also allows the teacher to influence the adaptation rules. All modules have been described along the variables manipulated by each of them.
In addition, it has been reported a comparison between alternatives concerning optimization techniques and computing intelligence that can be employed in the implementation of the Adaptation Module's algorithm. To illustrate how the Adaptive M-Learning works, an example of a typical situation has been described.
In summary, this architecture allows to build:

- a flexible environment, that enables the customization of learning objects mounting and obtention for a given course, and comprising several aspects of adaptation;
- an environment with "intelligence" to infer the need and suggest to the student a reinforcement of some topic of study.

At the time of writing this chapter the Adaptive M-Learning environment was an on-going research project. In order to have a complete environment, it was necessary to implement an algorithm using the reported optimization techniques and evaluate their complexities. It was also necessary to develop a simulator to illustrate how this environment works.

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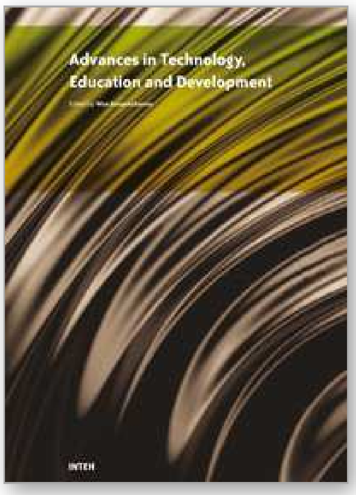

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From 3rd to 5th March 2008 the International Association of Technology, Education and Development organised its International Technology, Education and Development Conference in Valencia, Spain. Over a hundred papers were presented by participants from a great variety of countries. Summarising, this book provides a kaleidoscopic view of work that is done, all over the world in (higher) education, characterised by the key words ‘Education” and ‘Development’. I wish the reader an enlightening experience.

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