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T-MAESTRO and its authoring tool: using adaptation to integrate entertainment into personalized t-learning

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Abstract Interactive Digital TV opens new learning possibilities where new forms of education are needed. On the one hand, the combination of education and entertainment is essential to boost the participation of viewers in TV learning (t-learning), overcoming their typical passiveness. On the other hand, researchers broadly agree that in order to prevent the learner from abandoning the learning experience, it is necessary to take into account his/her particular needs and preferences by means of a personalized experience. Bearing this in mind, this paper introduces a new

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approach to the conception of personalized t-learning: *edutainment* and *entercation* experiences. These experiences combine TV programs and learning contents in a personalized way, with the aim of using the playful nature of TV to make learning more attractive and to engage TV viewers in learning. This paper brings together our work in constructing edutainment/entercation experiences by relating TV and learning contents. Taking personalization one step further, we propose the adaptation of learning contents by defining A-SCORM (*Adaptive-SCORM*), an extension of the ADL SCORM standard. Over and above the adaptive add-ons, this paper focuses on two fundamental entities for the proposal: (1) an Intelligent Tutoring System, called T-MAESTRO, which constructs the t-learning experiences by applying semantic knowledge about the t-learners; and (2) the authoring tool which allow teachers to create adaptive courses with a minimal technical background.

Keywords T-learning · Edutainment · SCORM · Personalization · Adaptation

1 Introduction

Governments in developed countries have been interested in distance education for many years. This interest is now growing due to the inexorable advance toward a global economy, because education is commonly regarded as the best way to maintain the competitiveness of regions. Thus, in recent years, we have witnessed a great development of e-learning technologies, up to the point that the use of the Internet as a medium to deliver educational material has practically displaced the early initiatives based on postal mail, radio or television.

Notwithstanding, the penetration of the Internet in homes has been rather limited (around 51,3% in Europe and 69,7% in the USA in June 2007[1]), while the number of homes with at least one TV set is much greater (almost 100% in both areas). From these data, it follows that the penetration of e-learning has been limited as well; in fact, it is mostly limited to enhance the training of people who already have a nice educational background. This has caused governments to be concerned about the *digital gap*, i.e., the separation between people that frequently use information technologies and those who have no access to them or, even having access, lack the necessary knowledge to use them. Unless some countermeasures are taken, this will lead to inequalities in the access to knowledge and education in the near future, being a possible source of social exclusion. To overcome these expectations, public administrations are promoting a variety of accesses to platforms different from the PC, mainly digital TV and mobile phones.

The recent advent of Interactive Digital TV (IDTV) opens a wide range of possibilities, because it allows broadcasting data and interactive applications jointly with the audiovisual contents. Thus, IDTV technologies enable distance learning solutions through fixed or mobile devices, each one with a different range of features. Surely IDTV can improve the paradigms and models used in *t-learning*, a term traditionally used when the learning process is through a household TV; but it is also a good opportunity to broadcast *m-learning* services, i.e. learning services for mobile devices as PDAs, mobile phones, etc. Moreover, these technologies make

[1] http://www.internetworldstats.com.

the access to distance education easier, since practically every home has at least one television set and the penetration of mobile phones in developed countries is nearly universal. Apart from wide-world usage, household TV and mobile phones are considered by the user as trustworthy in reference to their contents and easy to operate. It is commonly agreed that this may have far-reaching implications in education [28].

However TV-based interactive learning, whether t-learning or m-learning, is not just an adaptation for IDTV of the e-learning techniques used in the Internet. T-learning and m-learning have each one its own distinctive characteristics, mostly related to the constraints imposed by these media, such as the difficulty in reading text (due to the low resolution of the screen and/or the distance between the former and the user), the more limited capabilities to interact with the programs or the low processing power compared with a computer. Just as important as these technical constraints are the social ones, such as the predisposition of the users to education and their attitude when interacting with TV. The more than 50 years of analog TV have consolidated a fundamentally passive attitude of TV viewers, and also a conception of television as an entertainment medium. TV users have usually a lower predisposition than Internet users to get involved in learning experiences on their own initiative. Thereby, an effective t-learning strategy should be based on entertainment as the way to lure people into education, with special concern for those who have not been involved in educational activities for many years.

Moreover, for the successful development of TV-based learning solutions, it is necessary to learn from the experience accumulated during the evolution of e-learning, so as not to reproduce the errors that limited its expansion. This includes the absence of standardization, that often resulted in great development costs and limited reusability of educational resources, and the lack of support to overcome the feeling of isolation, which is frequently the reason why many people become soon disengaged and abandon the learning initiatives. Although it is common to all forms of distance learning, the feeling of isolation will be especially critical in this medium due to the inheritance of the non-interactive analog TV.

1.1 Motivation

Our previous work faces the problems mentioned above by proposing a framework for t-learning called ATLAS (*Architecture for T-Learning interActive Services* [38]). ATLAS provides a flexible solution for the development of t-learning objects and courses according to the guidelines of the worldwide accepted standard ADL SCORM (*Sharable Content Object Reference Model* [3]) to promote the reuse of learning elements in the context of IDTV. This framework offers as well a development environment called ATTOS (*ATlas TOol Support*) that allows, in a visual way, the creation of multiuser courses and learning elements consistent with the MHP (*Multimedia Home Platform* [17]) middleware specification, based on the aforementioned premises.

Once this work has been put into practice, we think that more emphasis should be given to two different facts that make TV viewers reluctant to education. On the one hand, their conception of the television as a medium for entertainment. On the other hand, their typical passiveness motivated by the more than 50 years of lying back on the sofa while watching TV. Taking these assertions into account, the proposal explained in this paper adds appeal and personalization to the courses created in the ATLAS framework.

In 1973, Robert Heyman coined the term *edutainment* to refer to strategies to attract students toward education through educational TV programs. Along the lines of edutainment, our work in this paper focuses on creating learning experiences that combine reusable educational elements and audiovisual ones (TV programs) to engage users in education, that is, learning experiences that combine entertainment and education. With this in mind, we propose two types of learning experiences: (1) *edutainment* (education that entertains) where the core of the experience is a learning element, in the traditional sense; and (2) *entercation* (entertainment that educates) where the central axis is a TV program with several learning add-ons.[2] By creating experiences which integrate education and entertainment at a different degree, we achieve learning experiences especially suitable for the habits of TV viewers.

Moreover, in order to engage users in learning even more, the experiences we propose are personalized according to user's preferences and learning background. Personalization is very important in t-learning, as the wide offer of channels can make users become disoriented; and also in m-learning, as mobile devices will be used for a short time, the users need to find only relevant information. In this environment, personalization permits the user to access those contents that are interesting for him/her and prevent him/her from getting lost in the huge amount of contents received, compensating to some extent for the typical passiveness of TV viewers. Since standardization and reusability are major milestones in a learning environment, we provide these personalized experiences by using an adaptive extension of SCORM (A-SCORM), turning ATLAS into an adaptive t-learning architecture where the same learning contents can be adapted to provide different forms of t-learning (entercation and edutainment) or to fit in with the t-learner characteristics.

Apart from a general vision of our edutainment/entercation approach, this paper shows our work in constructing these t-learning experiences, which includes the software modules for the two main roles in the experience: the content consumer—the learner—and the content provider—the teacher. Thus, special attention is given to the description of these two software modules: (1) the ITS (*Intelligent Tutoring System*), called T-MAESTRO (*T-learning Multimedia Adaptive Educational SysTem based on Reassembling TV Objects*), which has been incorporated into the ATLAS architecture to construct the t-learning experiences by applying semantic knowledge about the t-learners and the contents (both learning contents and TV contents); and (2) the authoring tool, *A-SCORM Course Creator Tool*, which allows teachers to create adaptive courses with a minimal knowledge of the ATLAS/T-MAESTRO architecture.

1.2 The SCORM standard

As we have explained above, our proposal creates learning experiences based on the ADL SCORM standard, for which we have proposed an extension in order for these

[2]Inside the term edutainment coined by Heyman, we distinguish two different forms of integrating education and entertainment: edutainment and entercation.

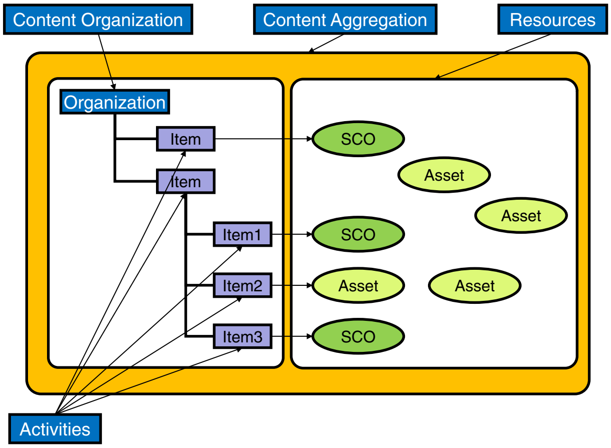


Fig. 1 SCORM content aggregation model

experiences to be adaptive. With the aim of providing a better understanding for the rest of the article, we explain, in this section, the basis of this standard. SCORM references specifications, standards and guidelines developed by other organizations that are adapted and integrated with one another to form a more complete and easier-to-implement model. It is divided into technical books grouped under three main topics:

- The *SCORM CAM* (Content Aggregation Model [5]) describes the components used to build a learning experience from learning resources and how they are aggregated and organized into higher-level units of instruction. It defines five different components (Fig. 1). *Assets* are electronic representation of media that can be collected together to build other assets. If this collection represents a single launchable learning resource that utilizes SCORM RTE (Run-Time Environment) to communicate with an LMS (Learning Management System),[3] it is referred to as an *SCO* (Sharable Content Object). An *Activity* is a meaningful unit of instruction that may provide a learning resource (SCO or Asset) or be composed of several sub-activities. To create a course, the activities compose a *Content Organization*, a map that represents the intended use of the content through structured units of instruction. Last but not least, a *Content Aggregation* is an entity used to deliver both the structure and the resources that belong to a course in a *Content Package*, which consists of a compressed file in PIF format (Package Interchange File) with the physical resources of educational content and at least one XML file—called *manifest* (*imsmanifest.xml*)—that embodies a structured inventory of the content of the package.
  The SCORM CAM defines also the metadata that should be used to describe these elements in a consistent manner, with the aim of facilitating the search and discovery of the components across systems. Although several standards can be used to express this description, SCORM strongly recommends the use of the IEEE LOM standard [21].

[3]In e-learning, the term LMS refers to the system designed to deliver, track, report on and manage learning content, learner progress and learner interactions.

- The *SCORM RTE* (Run-Time Environment [6]) defines: (1) the Launch process as a common way for LMSs to start Web-based content objects; (2) the API as the mechanism for exchanging data between the LMS and the SCO; and (3) a Data Model as a standard set of elements to define the information tracked by the LMS for each SCO.
- The *SCORM SN* (Sequencing and Navigation [7]) book covers the essential responsibilities of LMSs for sequencing content objects (SCOs or Assets) during run-time and allowing SCOs and learners to indicate navigation requests.
  The SCORM Sequencing Model allows the course creator to declare the relative order in which elements of content are to be presented to the learner and the conditions under which a piece of content is selected, delivered, or skipped during presentation.
  The SCORM Navigation Model, in turn, defines a set of navigation events that can be triggered by a learner through a user interface device provided by the LMS or embedded in content objects. How such events are triggered inside a SCO or through the LMS is not defined by SCORM.

1.3 Related work

TV channels are becoming more concerned about the possibilities of t-learning. In fact, their current efforts to develop and broadcast educational material are remarkable, although they are still focused on entertainment, so the material could be best described as edutainment [40]. However, there are some experiences closer to our proposal of enriching TV contents. For example, games and interactive stories for children, as well as documentaries with additional contents, like *Walking with beasts* produced by the BBC, in th UK; the "virtual magazines" of Canal Satellite in France where the viewer is aimed to be more active, although they cannot be coined as educational material [40]; or the educational applications developed by TVCabo in Portugal, some of them adapted from existing web sites, like *Ciberdúvidas*—resolving doubts regarding the Portuguese language [16].

Besides the efforts carried out by TV channels, there are some other proposals in the field of research that enhance TV programs with an educational aim. For example, the one explained in [18], where they are used to support language learning. Although this approach coincides with ours in combining TV programs and education, it uses the content of the programs directly as learning material, providing some help to the viewers by means of additional information sent to the user's mobile phone. On the contrary, in ours the content of the programs is not directly used for learning, but instead it acts as an entrance door to education or to make the learning experience more attractive.

In the same line but with different objectives, the system The Parent Trap [24] uses educational children programs to promote the conversations between parents and their children. When a children watches an educational program, the system sends the parent an e-mail to notify him/her about the period of time invested in watching it and the subjects explained on that period. It proposes as well a group of questions that the parent can ask the child to chat with him/her.

Last but not least, the proposal of [41] is closer to our entercation experiences in the sense that it tries to use TV programs to engage users in education.

The difference is based on the fact that this project allows TV viewers to indicate the subjects related to a program they are interested in and the system generates a web page to provide the information, whereas in ours the new information is offered without human intervention—but taking into account the user's characteristics—and is especially created to be watched on TV.

On another hand, and regarding the creation of t-learning courses, [1] explains the experiences obtained from a course for a group of eight students of a Master Degree in Computer Science. The course runs on a set-top box and interactivity is provided by a modem or ADSL as a return channel. It uses DVB-HTML learning material based on text and pictures. This work has taken a different direction than ours to create learning elements for t-learning. We conceive t-learning as a less formal kind of education, intended for complimentary learning, not as the main way to obtain knowledge.

To sum up, although this field is becoming more and more important, nowadays there are not many proposals which take advantage of the peculiarities of the interactive digital TV for educational purposes. From our point of view, personalization is one of the keys to take advantage of all the new possibilities that IDTV opens. Thus, we believe that personalization is a *must* to provide more entertaining courses for IDTV users, able to be interesting and engaging and based on less formal processes. However, there are few approaches to personalize courses for IDTV: [26] suggests personalized learning through IDTV by means of Broadband User Modelling and reusable educational contents [27] (that should be appropriately labelled); [34] explains several t-learning experiences developed by the BBC where different users are able to access different routes in the educational material or browsing it in different depths taking advantage of the interactivity of digital TV, but this process is performed by the learner instead of the system; and [39] studies the potential of digital TV for individualized language learning. Precisely, our proposal tries to fill this gap by making good use of the personalization experience compiled in the e-learning field.

In the personalization field, Adaptive Hypermedia (AH) is currently considered one of the most promising approaches to adapt hypermedia documents (links and contents) for users with different goals and knowledge, stored in a user model [12]. In fact, AH systems can be useful in any application area where the system is expected to be used by people with different interests. In the IDTV domain, AH techniques have been suggested to personalize some contents [30]: e.g. dimming an item by showing it in a smaller screen portion when it is not particularly interesting for the viewer, offering additional information for the user when he/she has little knowledge about the subject proposed, etc.

However, in the learning domain, the widely-known SCORM standard only provides a simple adaptation based on the sequencing information (a modification to these information in order to provide adaptation is exposed in [8]). Its main goal is to ensure that a learner completes all the activities that an instructor deems important, while avoiding those that may be unnecessary. Thus, the SCORM attempt is instructor-centered instead of being user-centered, as AH promotes [2]. Our approach is a hybrid between both options, being instructor-centered, like in SCORM, because the student has to complete all the activities that the instructor considers important for him/her, and user-centered, like in AH, due to the adaptation of the course in an effort to become more appropriate for him/her.

The use of e-learning standards in AH educational systems has already been studied in the literature [37, 49] and several proposals have arisen to provide SCORM with some type of adaptivity. One of them is the SCORM Dynamic Appearance Model [23], which is centered in providing SCOs developed by different organizations with similar appearances by means of CSS and XSLT technologies, which improves the reuse of contents since it makes the appearance of the courses uniform. Another proposal in this area is explained in [33], where the requirements on an e-learning standard for adaptivity support are established. ADL SCORM is inspected and the authors suggest exemplary enhancements to support adaptive e-learning. These enhancements consist in improving SCOs with several mappings instead of a fixed one. Our proposal differs in that our self-adaptive SCO configures itself according to user's characteristics, whereas in [33] an ITS should make the selection of the appropriate mapping. Moreover, it does not define a general framework for the SCOs to work in.

Last but not least, the project KOD (*Knowledge on Demand*) [48] builds on an extension of the IMS Content Packaging specification (the same adopted by SCORM), for the description, in a common format, of knowledge packages, i.e. collections of learning objects, together with rules which determine how they should be selected for different learner profiles. These rules relate learning objects to one another, learning strategies with learner goals and user profile characteristics with values in some of the categories of learning objects metadata in order for them to adjust to this profile.

1.4 Structure of the paper

In the next section, we provide a general overview of our edutainment/entercation approach as well as sample scenarios which illustrate the kind of experiences we propose to attract a TV viewer toward education. In Section 3, we introduce the proposed ATLAS/T-MAESTRO architecture and the main roles in t-learning experiences. After that, we focus on the extension to the SCORM standard to provide adaptivity (A-SCORM) and its authoring tool (Sections 4 and 5). The we explain the system responsible for creating the personalized experiences: T-MAESTRO. Sections 6 and 7 present the conceptual innovations which lie behind the process of creation of personalized learning experiences. Finally, we evaluate the system in Section 8 draw some conclusions (Section 9) and introduce future lines of research (Section 10).

2 Overview of our proposal

Despite the fact that much of the work in this paper is applicable to TV-based learning (either m- or t-learning), hereafter we shall focus on t-learning experiences and we postpone the discussion of its application to other fields for Section 9.

To create these experiences, it is necessary to bear in mind the behavioral differences between e- and t-learners. E-learning users get consciously involved in educational activities to enjoy the advantages of distance learning. Because these users play an active role, e-learning environments implement *user-driven* strategies for interactivity, in which the applications respond to the users' actions. On the contrary, in t-learning environments, the users' more passive role recommends *media-driven* strategies in the implementation of the interactivity, so that the users are guided through the contents and take part in a reduced number of decisions. These media-driven strategies are suitable to exploit the multimedia capabilities of IDTV, coherent with the fact that courses for IDTV should be based on audio and video in a natural way.

Taking these facts into account, e-learning and TV-based learning should have different scopes. Whereas the former is highly adequate for formal education settings with well-defined methodologies to achieve certain curricula, the latter is more suitable for an informal approach [13]. From our perspective, an effective t-learning strategy should be based on entertainment as the way to lure people into education, with special concern for those who have not been involved with educational activities for many years. Thus, we conceive t-learning just as an intermediate point between pure entertainment, as in traditional TV, and education, which we identify with e-learning.

2.1 The new t-learning experiences

Our approach provides light learning processes by integrating entertainment into education in different degrees and personalizing the resulting experiences. These experiences are created by an ITS (Intelligent Tutoring System)[4] that collaborates with the TV recommender system AVATAR already developed by our research group [11].

For this to be possible, our system needs to store in the user's profile his/her preferences as a viewer and a learner, as well as his/her educational background with the aim of filtering out those contents that are not interesting and those that are too difficult or too easy for him/her. This profile will be further explained in Section 6.2.

The process of creation of the experiences takes place in several steps, first, AVATAR and the learning content selection module of the ITS work independently to select the appropriate audiovisual contents and learning contents (respectively TV and LE in Fig. 2). They store in a local database the TV contents and LEs that are appropriate for the target user. Then, the adaptation module adapts LEs for the particular user's preferences and, finally, the composition module creates the learning experiences.

Depending on the kind of relationships between the learning and audiovisual contents, we have defined two forms of t-learning experiences: entercation and edutainment. Besides, since we add to LEs the capability of being adapted, we can talk about adaptive entercation and edutainment (see Fig. 2):

- *Entercation* deals with '*entertainment that educates*'. Its central element (Fig. 2a) is a TV program (TV) that is complemented with LEs. The construction of *entercation* experiences is initiated by the selection of a TV program interesting for the viewer (a TV recommender is needed). Then, the ITS has to choose the most appropriate LEs related to the characteristics of the program among those which are interesting for the user. These selected LEs will be offered to the user

[4] An Intelligent Tutoring System (ITS) is a computer system that provides direct customized instruction to students, without the intervention of human beings.

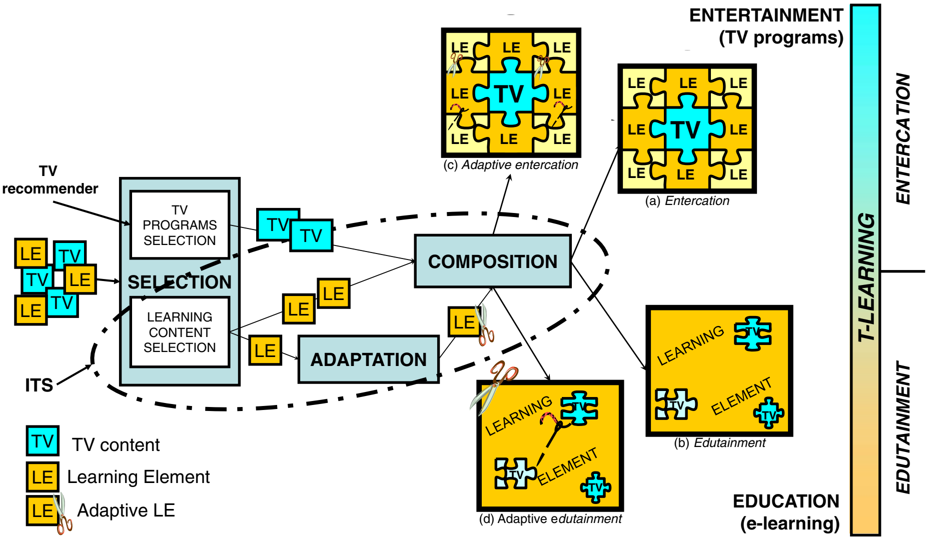


Fig. 2 Creation of t-learning experiences

during the program. Thus the TV program acts as a bait to engage viewers in education.
In SCORM terminology, entercation experiences consist in offering additional educational information in the form of any type of SCORM element, from an asset to a complete course. However, we think that it is very important not to overwhelm the user, that is why it is more appropriate to just offer a small piece of content (such as a SCO or an activity) that can serve as a bait to engage user in more complex educational experiences such as complete content organizations or courses.

- *Edutainment* refers to '*education that entertains*'. Its central axis is an LE (Fig. 2b), which will be complemented with TV programs to make the experience more entertaining and attractive to the student. The ITS creates an edutainment experience from an LE that it considers appropriate for the student, according to his/her learning interests. At the appropriate point, it adds some relevant audiovisual elements (that may be of interest to the student), according to the learning content, in order to make the experience more entertaining.
Using SCORM to deliver these experiences, edutainment consists in adding new assets to a some activities or SCOs. These new assets are programs or segments of programs related to the course and interesting for the student.
- Finally, if we add adaptivity to these experiences, **adaptive** entercation and edutainment experiences can be obtained (Fig. 2c and d). In these experiences, an adaptive LE is an LE which can be adapted in order for the student to achieve some objectives in an appropriate way according to his/her characteristics [12]. Providing personalization through adaptive LEs promotes reusability, since it becomes more probable to find a LE which fits in with the user profile. If the LEs were immutable it would be very hard to find an appropriate LE for every single user.

In order to create adaptive learning elements in the scope of the SCORM standard, we have proposed an extension to this standard that we have presented in [47] and we summarize in Section 4.

To conclude, and leaving adaptation aside, we consider that in edutainment the user is interested in learning, whereas in entercation the learning process is more casual, without a clear intentionality from the viewer. Consequently, edutainment might involve more formal pedagogical experiences while in entercation less formalization is clearly more adequate.

2.2 Sample scenarios

In this section, we discuss sample scenarios for entercation and edutainment.

Entercation: Assume that the user (possibly guided by the TV recommender) has selected the movie "Under the Tuscan sun". Besides, the ITS has selected some learning elements for the viewer (according to his/her interests, using AVATAR's semantic reasoning algorithms) which include an Italian course, a SCO about sharks, a documentary about The Campania region, a course of renaissance art and an activity about dinosaurs. Among them, only those which are related to the movie plot are selected: the Italian course and the course of art (the story takes place in Italy) and the documentary about the Campania region (the Italian region where some scenes are located). These elements are linked to the movie and the user has the option to choose them.

Edutainment: Assume that the user has decided to follow a course to improve Italian listening comprehension. With the aim of making the course more attractive, the ITS chooses a related TV program among those that the TV recommender has previously selected. So, the user is given the opportunity to watch the famous Italian contest "*Fratelli di Test*" to practice listening comprehension.

Note that both experiences should consider not only the relationships between contents, but also information about the user to select the extra contents. Our aim is making the learning experience more attractive, not to produce the opposite effect. For instance, if the user has an average level in Italian and the system offers him/her a course for beginners supplementing "Under the Tuscan sun", he/she will probably get bored and will not be engaged in the entercation experience. The same would happen in edutainment: if the viewer does not like TV contests, offering "*Fratelli di Test*" would certainly not be a good choice. Consequently, the user's profile must store both: the user's characteristics as a viewer and as a learner.

3 Roles and software in the t-learning scenario

Due to the enormous variety of contents and the considerable range of users, even though interoperability and reusability are essential premises for a t-learning solution, they are not enough on their own. In addition, the t-learning experience should be personalized according to the user profile and should be constructed by integrating audiovisual and learning contents. Both aspects are essential to provide the entercation and edutainment experiences so that education is perceived by the user in a more attractive and effective way—since the experiences take into account his/her preferences and learning background and they are appropriate to

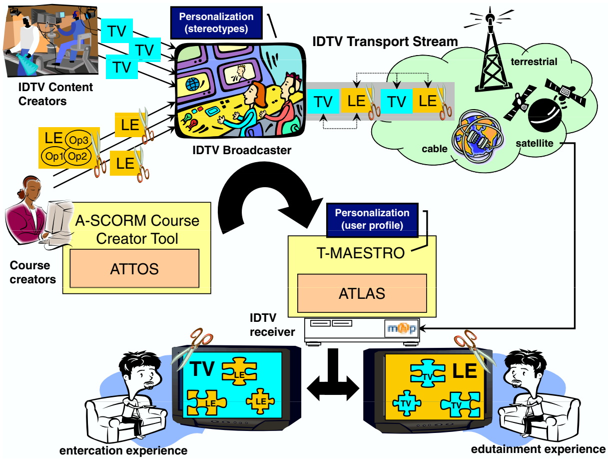


Fig. 3 Roles and software entities in the t-learning architecture

his/her TV habits. In order to relate TV and learning contents as well as to support the personalization process, we propose a semantic approach which avoids the drawbacks of simple syntactic matching and makes the information amenable to powerful inference mechanisms.

In this context, we have studied the role played by the main actors in a typical broadcast scheme (see Fig. 3): the *course creators*, *IDTV content creators*, *IDTV broadcasters* and *IDTV receivers*. Due to the limited resources in IDTV receivers, we propose dividing the integration and personalization tasks between the receiver and the broadcaster so that the receiver has only a reduced set of possibilities to personalize.

3.1 Course creators

Course creators are in charge of designing adaptive t-learning elements (Fig. 3), i.e. educational content or whole courses whose information or the way this information is shown may be different according to the specific viewer's characteristics. To do this, we have defined an extension to SCORM to provide adaptivity, A-SCORM in Section 4; and a specific ontology (Section 6.1) to properly organize the new learning elements and to allow to establish semantic relationships among contents—this ontology has been previously introduced in [45].

With the aim of providing a friendly environment for designers to define these adaptive learning elements, we have implemented an authoring tool named *A-SCORM Course Creator Tool* (Section 5). This tool has been constructed on top of our previous tool ATTOS (*ATlas TOol Support* [25]), so it integrates some of the ATTOS features and, additionally, it provides support for defining adaptive courses with A-SCORM.

3.2 IDTV content creators

IDTV content creators provide broadcasters with entertainment contents: traditional audiovisual contents (like movies, TV shows or documentaries), textual information, interactive applications, etc.

According to our objectives of relating educational and entertainment contents, both of them should be conveniently labeled and modeled. As mentioned before, learning contents are modeled according to the SCORM ontology by course creators, so, a learning element is an individual in the appropriate point of the ontological structure. On the other hand, TV contents should also be modeled. For our system, IDTV content creators should mark up the contents with the metadata defined in the TV-Anytime specification [51]. These contents are organized in an ontological structure as well, an ontology for TV contents in this case (Section 6.1).

3.3 IDTV broadcasters

IDTV broadcasters issue both entertainment and educational contents and, with the aim of attracting TV viewers, we propose they establish relationships among them (indicated using the mechanisms provided by the TV-Anytime specification [51]). These relationships are based on the subject matter of the contents. For instance, the movie "Under the Tuscan sun" could be related, according to a thematic criterion, to a course about learning Italian, to a documentary "Relevant architecture of Tuscany", to a course "Tuscan wine roads", etc.

But, IDTV broadcasters not only use the semantic information that labels the received contents, but also the information about target groups of potential viewers or stereotypes. A stereotype is a popularly held belief of a type of person or a group of people which does not take into account individual differences.[5] Having general information about stereotypes, the broadcaster can alleviate the personalization costs which would be needed at the receiver side. Thus, the IDTV broadcaster marks up the previously established links with information about the stereotypes for which this relationship would be appropriate. For instance, the link to "Relevant architecture of Tuscany" is appropriate for people with an educational background close to the architecture field; the link to "Tuscan wine roads" for users interested in wine; etc.

To create the links between the TV programs and the additional contents, as well as to express the characteristics of the target users, TV-anytime metadata are used [51]. TV-anytime allows the segmentation of contents and the description of these segments by means of keywords, as well as indicating related material for these segments. This is the mechanism used to relate the TV program to the additional contents. Concerning the characteristics of the users the additional contents are intended for, they are expressed by means of the Targeting Information of TV-Anytime metadata.

So, the personalization process is a two-step process. In the coarse step, at the broadcaster side, relationships among contents are obtained and associated with specific stereotypes. In the fine step, at the receiver side, these relationships are filtered without starting from scratch, which alleviates the computational costs for the IDTV receiver.

[5]Our use of the term stereotype obviously lacks the negative connotation present in general usage.

3.4 IDTV receivers

Finally, the broadcast contents (entertainment and educational ones) are received at home and the IDTV receiver adapts them to the TV viewer's interests providing both entercation and edutainment experiences. Since broadcast contents have been linked according to the information kept by the IDTV broadcaster (thematic and stereotypes), personal differences must be taken into account at the receiver side to filter links and to adapt the learning contents.

An essential factor to succeed is keeping information about the user, i.e. his/her user profile (see Section 6.2). Shortly, this profile stores the learning background, personal information (job, age, etc.), TV tastes (documentaries, movies, etc.), multimedia preferences, thematic interests, hobbies, etc. By applying this information, the received contents can be tailored and, in this manner, the educational experience will be more satisfactory. All these tasks will be carried out by T-MAESTRO which is the ITS we propose whose functionality and stages are explained in Section 7.

4 Personalization through A-SCORM

As mentioned above, we propose improving t-learning experiences by integrating TV programs and LEs and, additionally, by adapting the latter to user preferences, i.e. personalizing them. In this regard, the Overview book of the SCORM standard repeatedly mentions the importance of personalization in education. It even cites the discovery and assembly of educational objects on demand. However, its current adaptation abilities are very restricted and they are focused on two main aspects.

On the one hand, SCORM allows to define several content organizations for the same course. Nevertheless, most SCORM-conformant LMSs (*Learning Management Systems*)[6] implemented up to now, as Blackboard (http://www.blackboard.com) or Desire2Learn (http://www.desire2learn.com), do not store any user profile information and, at most, they let the election in the user's hands by offering him/her the titles of the organizations. On the other hand, SCORM defines a default set of sequencing information that governs sequencing for a specific content organization. Although SCORM sequencing information can be considered adaptivity in some way, it is only based on some criteria corresponding to the particular course and does not permit taking into account external aspects such as user's preferences or learning background.

Consequently, we propose to extend the SCORM standard with the purpose of providing it with adaptation ability. In this manner, the course creator can offer different options instead of a fixed one in some points of the course, indicating, for each one, the characteristics of the target user. As a result, adaptive courses will be created so as to be adapted to the user's characteristics before he/she studies them.

[6] A SCORM-conformant LMS is the one that adheres to the requirements exposed in [4]. There are three categories of conformance for LMSs, corresponding to the SCORM three main topics: RTE, CAM and SN. A SCORM-conformant LMS should be able to import Content Aggregation Packages using PIF format, launch a learning resource (SCO or Asset), implement SCORM RTE API and data model, implement SCORM navigation data model, adhere to the Content Aggregation Model and implement SCORM sequencing behaviors. If an LMS is derived from the standard but has not been given a conformance test, it is said to be compliant.

For this to be possible, we propose two extensions—but not modifications—to SCORM, to provide it with adaptivity: the first one to adapt the structure of the course (extension at activity-level, Section 4.2) and the second one to adapt the learning objects behavior (extension at SCO-level, Section 4.3). In both cases, the adaptation ability is constructed from a set of adaptation parameters which can be computed for any target user as we describe in the following section.

4.1 Adaptation parameters

Apart from the capability of adapting a SCORM course, both at SCO and activity level, one missing element is the set of parameters according to which this course is adapted. At first, each single user characteristic stored in the learner profile could be used as an adaptation parameter. However, apart from constituting an unmanageable amount of information for a human course creator, these characteristics depend on the ITS used.

Bearing this in mind, we propose to define a new role, the *vocabulary creator*, who is responsible for: (i) extending the SCORM data model with new vocabularies of adaptation parameters; and (ii) providing the ITS (T-MAESTRO in our proposal) with inference rules. These inference rules establish relationships between adaptation parameters and user's characteristics from the user profile. This is the most relevant task in the role of the vocabulary creator because it makes it possible for the extensions proposed in this paper to work independently of how the user profile is stored in the ITS.

Therefore, as Fig. 4 shows, the vocabulary creator establishes a set of adaptation parameters and provides the ITS with the corresponding inference rules.

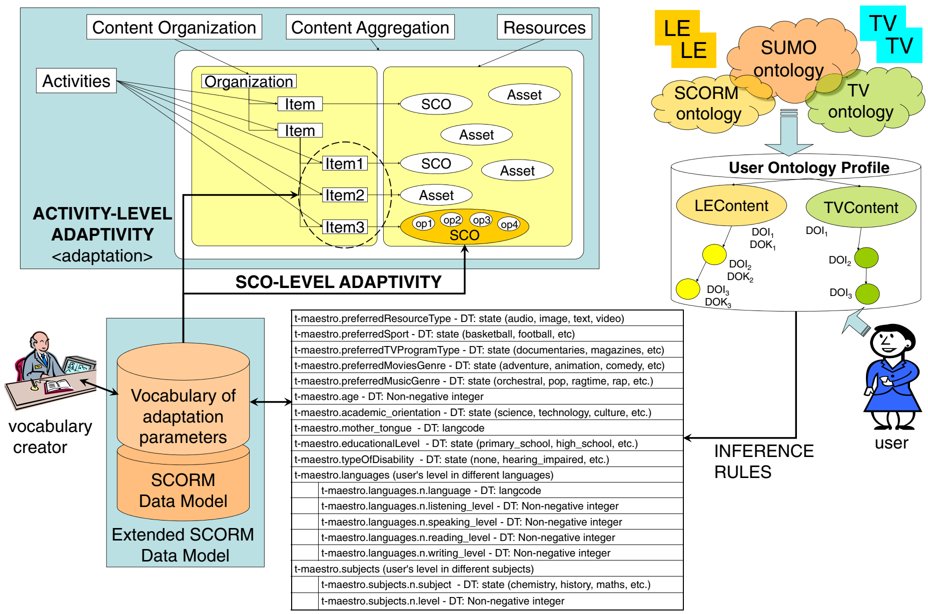
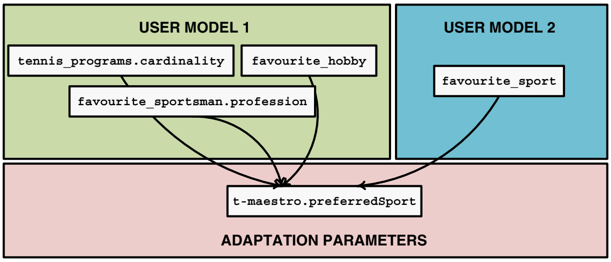


Fig. 4 General structure of adaptive SCORM

Fig. 5 Example of inference rules for different ITSs



Consequently, he/she must know the user model of the ITS responsible for the adaptation (T-MAESTRO in this case), preventing the course creator, in charge of the pedagogical aspects, from this specific task. The example of Fig. 5 offers an example of the mapping between the elements of the user model and some adaptation parameters (this mapping is what we call inference rules) to determine user's favorite sport, for two ITSs with different user models.

This information is not directly stored in the user model of the ITS on the left, so, it has to infer this value from other characteristics. Conversely, the inference is trivial in the ITS on the right, since it has in its user model the user's favorite sport.

Finally, the ITS, by using the inference rules, obtains the relationships between the specific elements of the ITS user model and the adaptation parameters. At the bottom of Fig. 4, we can see some relevant user characteristics for the IDTV learning scenario suggested, as well as a possible set of values for them to take. However, the set of adaptation parameters defined in this section is not static. New adaptation parameters can be created by vocabulary creators as long as ITSs are provided with inference rules for these parameters.

4.2 Extensions to SCORM: activity level

Adaptivity at activity level allows the adaptation of the course structure according to the user's preferences and learning background. The course creator can establish a group of activities to achieve a learning objective, in such a way that the student does not need to study all of them but only those ones contributing to his/her knowledge

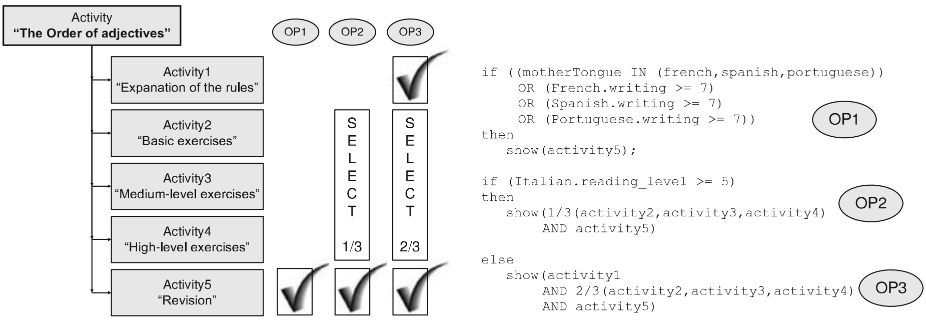


Fig. 6 Example of adaptation at activity level

or adapted to his/her preferences. With this aim, the course creator provides a set of adaptation rules attached to the activity structure. Thus, a given set of activities is considered to be appropriate for a particular student whenever he/she fulfills the conditions specified by its adaptation rules.

For a better understanding of this type of adaptation, Fig. 6 shows an example of an activity devoted to learn how to place adjectives in Italian, composed of 5 items: the first one exposes the theory, from second to fourth several exercises are proposed and the last one deals with revision. Depending on the background of the student, not all these items need to be studied. For example, if the student is Spanish, he would already know how to place the adjectives, since it is very similar in all Roman languages. In this case, it would be enough to study the revision activity to refresh the contents. So, the course creator establishes the following adaptation rules (shown in pseudocode in Fig. 6(b)): if the user has a Roman language as a mother tongue or has a high writing level in any of these languages, the revision activity is the only one needed (OP1). If this is not the case, but the user has at least a medium level reading Italian, he/she will know some basics about the order of adjectives, so, only one of the three practical activities (2, 3 and 4) and the revision unit (activity 5) are offered (OP2). Otherwise, the student has to study two of the three exercises activities and the revision one (OP3).

The educational information for an adaptive course is totally specified in its manifest (*imsmanifest.xml*) file. Apart from the different organizations and sequencing information defined by SCORM, we have included in this file the adaptivity at activity-level (conditions, rules, etc.) encapsulated under the tag `<adaptation>`.[7] As SCORM allows to define more than one organization for the same course, adaptation rules can be used not only to help the LMS to decide which are the activities that are more relevant for the student but also among the different organizations available. At the bottom of Fig. 7 we show an example of this syntax for the second adaptation rule mentioned above. More information about this type of adaptivity is available in [47].

At runtime, the LMS analyzes the manifest of the course, to know which activities must be shown to the final user and the correct order to do so. To obtain the definitive sequence of educational elements, the LMS must know the current values for the adaptation parameters, which are inferred from the user's profile (Fig. 7).

4.3 Extensions to SCORM: SCO level

Whereas the first extension allows to adapt the organization (structure) of the educational resources in a course, adaptivity at SCO-level permits the adaptation of the educational resources themselves. In this case, the extension we propose takes place within the data model of the SCORM RTE (*Run-Time Environment*). The SCORM RTE book defines a data model to store the information obtained from the user interaction with the SCOs belonging to a course, which deals mainly with the objectives to achieve in this course. A SCO can read and write the values of the

[7] Following the SCORM Content Aggregation Model (CAM) recommendations, `t-maestro_idtv_det_uvigo_es` is used as the namespace, like we have done for the creation of new adaptation parameters.

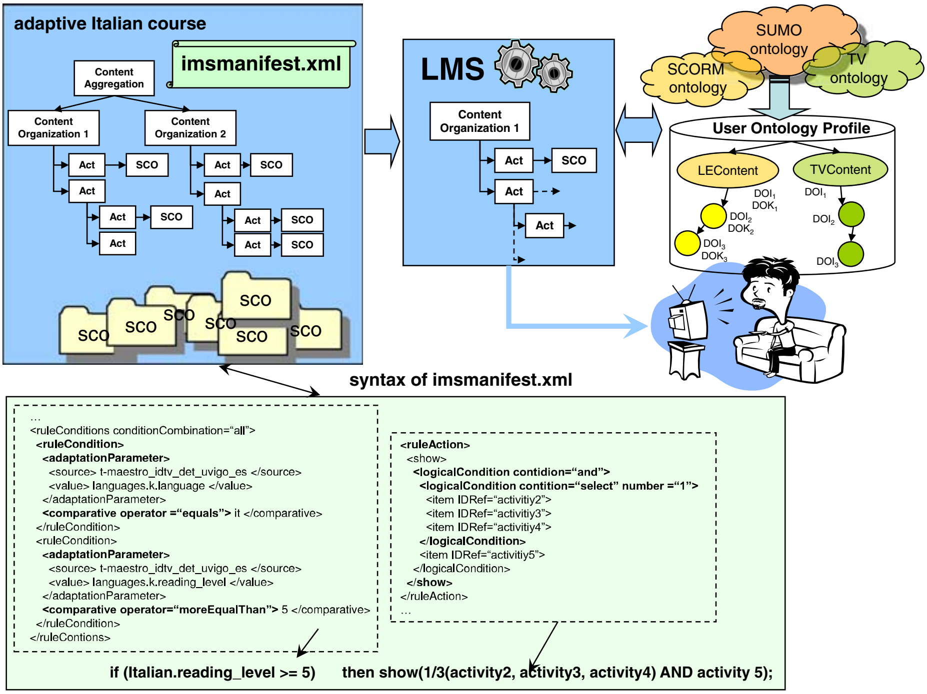


Fig. 7 Operation of an adaptive course

elements of the data model through the methods provided by the communication API, and this is the only way for it to send/receive information to/from the outside.

As mentioned before, we add a set of adaptation parameters to the SCORM data model whose values for a target user allow to adapt the SCO behavior at runtime. Once we have an extended data model for adaptivity, a self-adaptive SCO needs some adaptation rules to decide which behavior it has to show, based on the user's characteristics. As specified in the SCORM standard, SCOs (adaptive SCOs as well) have the ability to communicate with the LMS to obtain the actual values of these characteristics (specific values of the adaptation parameters).

4.3.1 Physical structure of a self-adaptive SCO

Having no other restrictions about SCO operation in the standard, we propose self-adaptive SCOs physically composed by: a Java template, several configuration files, an adaptation file and multimedia contents (see Fig. 8). The Java template contains the SCO functionality, for example, a Java class with some space for text, a video, a picture and some control buttons. Each configuration file is an XML file which specifies the behavior of the SCO for a particular option. It indicates which objects take up the spaces in the template as well as the properties of these objects, such as color, position, etc. There are as many configuration files as different behaviors the SCO can adopt. The adaptation file is also an XML file containing the adaptation rules that indicate the SCO which is the most appropriate behavior to adopt, i.e. which configuration file to be used (the syntax of these files, partially shown in Fig. 9,

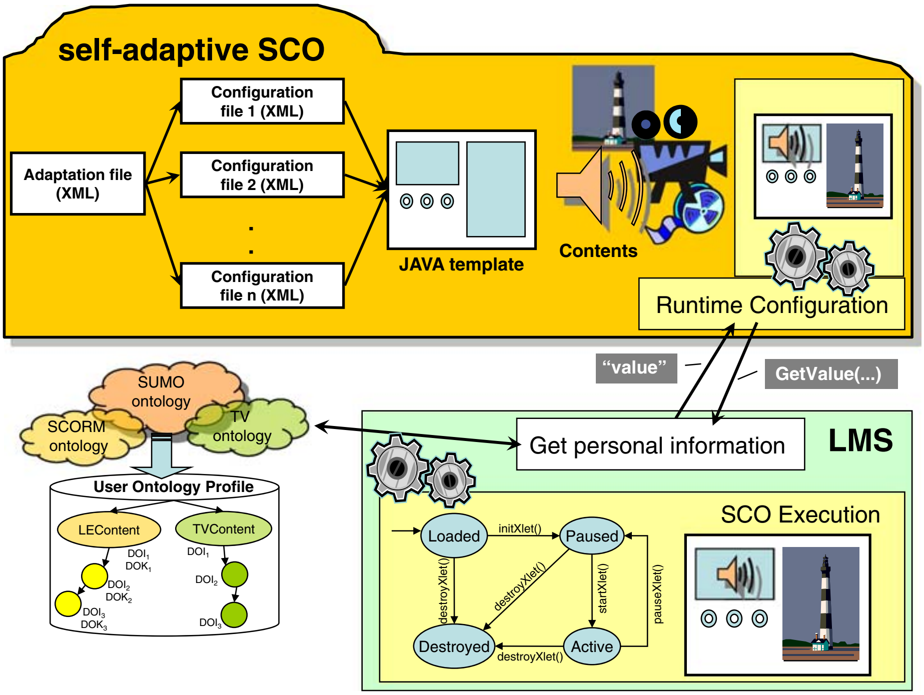


Fig. 8 Self-adaptive SCOs: structure and self-configuration

is very similar to the one used to express the adaptation rules at activity level). Self-adaptive SCOs communicate with the LMS to obtain the values of the adaptation parameters for the specific user to obtain the personalized SCO.

In order for this Java class to work properly in the MHP context, it should be compliant with the DVB-J model defined in the standard [17]. DVB-J applications, commonly referred to as *Xlets*, are Java programs with two restrictions: the APIs they are allowed to use and their life cycle. So, *Xlets* should follow a life cycle that allows an external entity to initialize, pause, restart and destroy them by means of an established interface, as shown in the bottom part of Fig. 8.

4.3.2 Self-adaptive SCOs at run-time

The behavior of a self-adaptive SCO when launched by the LMS is shown in the bottom part of Fig. 8 and is detailed in Fig. 9. In this case, the SCO belongs to an Italian course and its mission is helping the learner with listening comprehension. With this aim, a video or audio—depending on his/her preferences—with subtitles is shown to the student. So, the SCO firstly reads the adaptation file to see which are the adaptation parameters it needs to know in order to resolve the adaptation rules (step ➊). In this case, the adaptation parameters needed are `preferredResourceType` (audio or video) and `preferredSport` (tennis, football, basketball, etc.). Next, it requests from the LMS the actual values of these parameters for the particular user, through successive calls to the `GetValue()` method of the SCORM RTE API (step ➋). The LMS returns `video` and `tennis`. With these values, it resolves

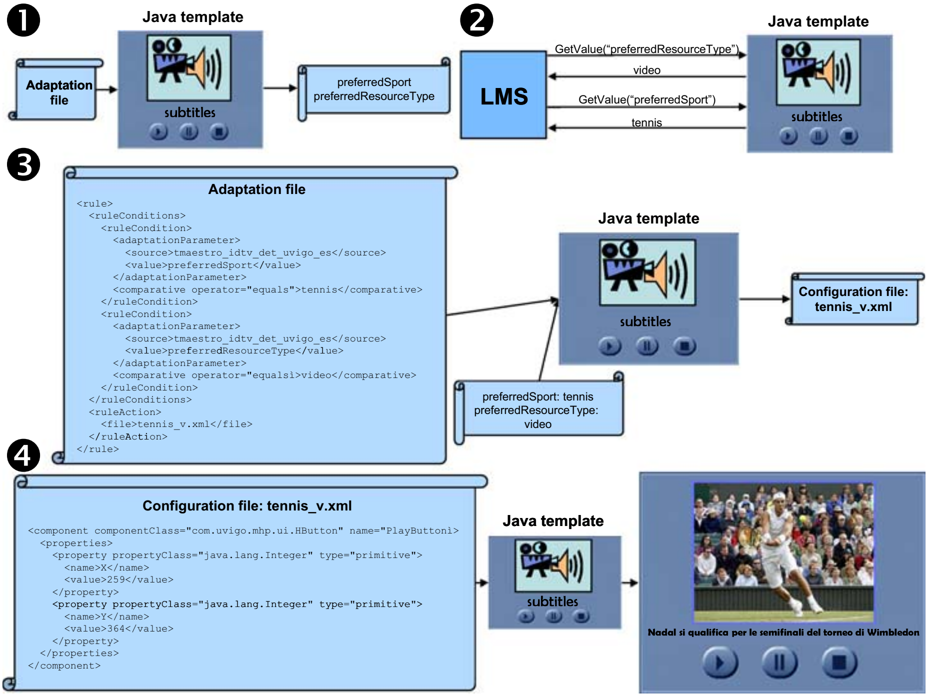


Fig. 9 Operation of a self-adaptive SCO

the adaptation rules in the adaptation file in order to know which configuration file to use (step ❸) Some of the rules for this example in pseudocode are as follows:

```
if ((t-maestro.preferredSport == football)
    AND (t-maestro.preferredResourceType == audio))
then //Rule action
    file = football_a.xml;
if ((t-maestro.preferredSport == tennis)
    AND (t-maestro.preferredResourceType == video))
then //Rule action
    file = tennis_v.xml;
```

The Configuration File (*tennis_v.xml*) contains the properties of all the objects in the Java Template of the SCO, so as it can take the appropriate behavior for the target user (step ❹). The syntax of these file is proprietary of each SCO, in our implementation we use an XML file that lists all the Java objects of the template and their properties that have been modified from the original. As an example, Fig. 8 shows a piece of one of these files where the properties of one of the control buttons are shown.

5 A-SCORM authoring tool

After exposing the proposal to create adaptive learning elements based on SCORM, it can be argued that it is too technical for content developers, since they would have to know Java programming, adaptation and configuration files syntax in XML, as well as technical details of the SCORM standard. This problem, already identified in [53], is based on the separation between teachers, who are not usually experts on the technical side, and programmers, that do not have to be experts in pedagogy. In order to solve this problem and make the proposal feasible, we have developed an authoring tool, A-SCORM Course Creator Tool (see Fig. 10), to construct adaptive SCORM-conformant courses. This authoring tool includes the submodule SCO Creator Tool which allows creating self-adaptive SCOs. The SCO Creator Tool uses the functionality previously developed in ATTOS [25] to specify contextual bindings among the different types of multimedia contents. This mechanism is based on the interrelated fragments (referred to as *contexts*) in the different types of information. Necessarily, the context are delimited differently in the different types of media (by timestamps in pieces of audio and video, by lines in pieces of text, by regions in images, etc.), but they are always given a name, which is used to keep the different components of an SCO in the same context.

Besides, we have developed three additional sub-modules for defining options, adaptation rules and SCORM metadata, respectively. The resulting self-adaptive SCOs are stored in a repository, ready to be used to build courses. These courses are

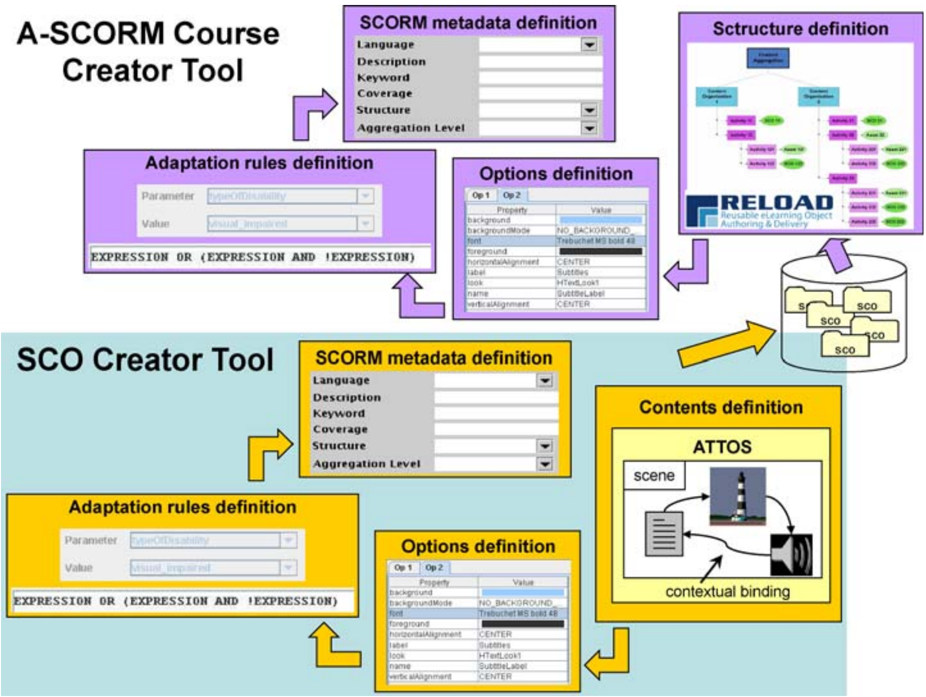


Fig. 10 Schema of the authoring tool

built by using the A-SCORM Course Creator Tool, which enriches the functionality previously developed by the RELOAD Editor [42] by adding new functionality that allows specifying different organizations for SCORM courses. We have enriched the RELOAD Editor functionality to define adaptivity at activity-level and to retrieve self-adaptive SCOs from the intermediate repository.

In the following sections we describe both the course and the SCO creator tools in order to offer some details of implementation and to provide the reader with a general vision of the system about the conceptual basis in the previous sections.

5.1 A-SCORM course creator tool

The A-SCORM Course Creator Tool adds new functionality to the RELOAD project [42] to build whole courses. The key aim of the RELOAD project is the implementation of a reference-standard Content Package and Metadata Editor. The RELOAD Editor enables course creators to organize, aggregate and package

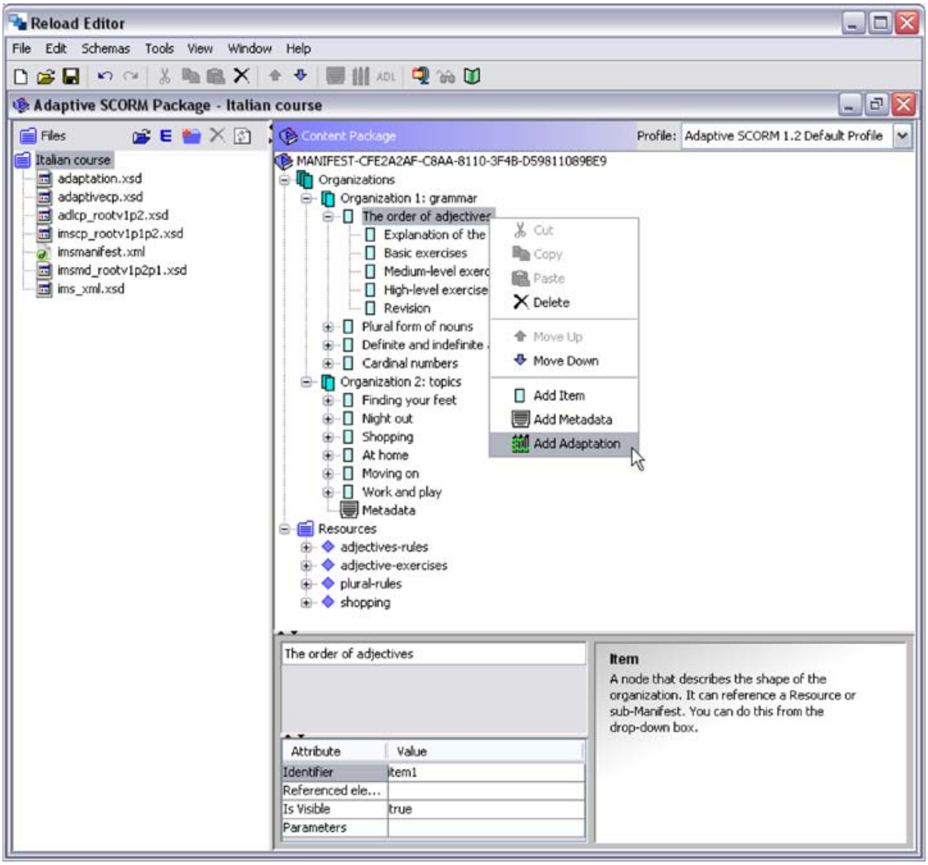


Fig. 11 A-SCORM course creator tool

learning objects in standard IMS and SCORM content packages tagged with metadata (in various subsets) and vocabularies.

Figure 11 shows the appearance of the A-SCORM Course Creator Tool while a course creator is building an adaptive Italian course. This course is structured into two organizations: one focuses on grammar contents, and the other on practical conversations. Obviously, according to our point of view, the course creator specifies the characteristics of the target students for each organization by means of the appropriate adaptation rules. For instance, the first organization is recommended for students especially interested in learning Italian in a more formal way. However, the second one is suitable for tourists going to Italy.

Over RELOAD's functionality, we have added two new sub-modules to be able to create the adaptive courses we have defined (Fig. 10). The first one, shown in Fig. 12, is an adaptation rules editor that permits content creators to easily define the conditions and actions of adaptation rules at activity level, in a more intuitive manner, avoiding them the tedious task of writing them in the XML syntax. Adaptation rules can be attached to any activity with child activities or to all the organizations. In the first case, adaptation rules can refer to any descendant activity; in the second one, they should refer to the existing organizations. This new module shows the adaptation parameters available, as well as their allowed values; it also permits to edit the conditions by means of logical expressions, allowing the use of parenthesis for nesting; and shows all the descendant activities or organizations available. When the user finishes creating the rules, they are validated to detect inconsistences and translated to XML syntax to be written on the manifest of the course.

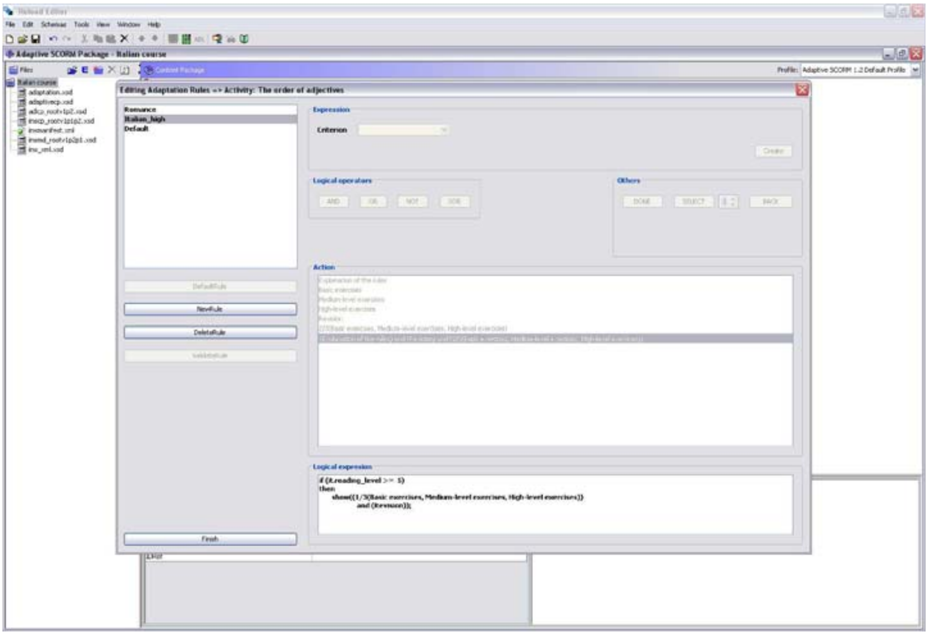


Fig. 12 Adaptation rules in A-SCORM course creator tool

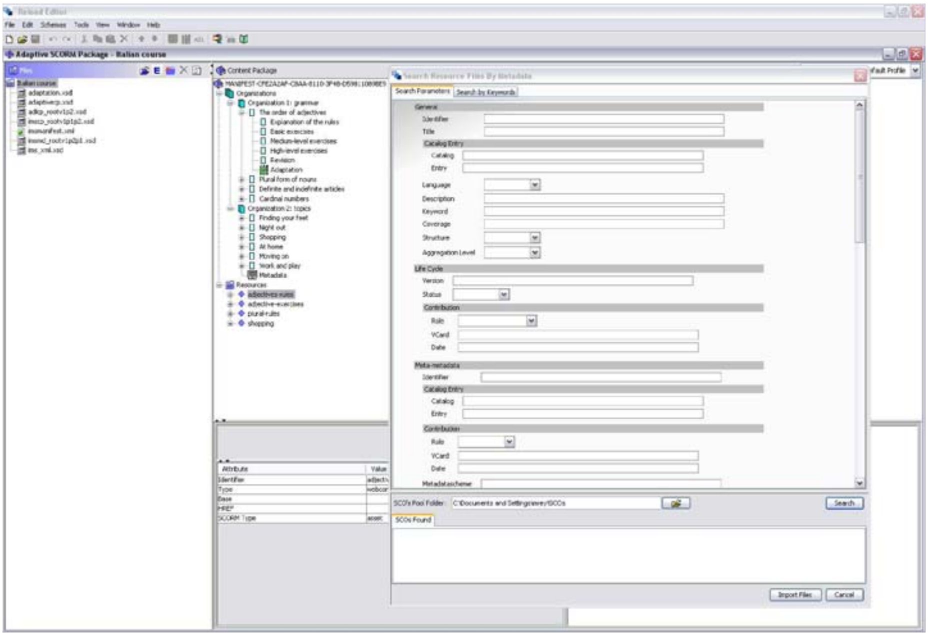


Fig. 13 SCOs discovery in A-SCORM course creator tool

The second module that we have added to this tool is the SCO repository (Fig. 13) that permits to include adaptive SCOs created with SCOCreator in the course being created, providing a searching engine that allows to look for the appropriate SCOs performing a metadata or keyword-based search. When the user selects a SCO, it is directly included in the course package and referenced in the manifest.

5.2 The SCO creator tool

The SCO Creator Tool has been specially designed and implemented to develop self-adaptive SCOs in a friendly way. Since SCORM does not restrict the internal operation of a SCO, we have defined the physical structure of self-adaptive SCOs taking into account only the DVB-MHP restrictions (see Section 4.3.1). With the SCO Creator Tool, a user without any Java programming experience can create self-adaptive SCOs following the steps described next.

Content creators can specify the appearance of the different options as well as the configuration and adaptation files of the self-adaptive SCOs. All these tasks do not require the content creator to be familiar with Java programming and XML files:

Selecting the template The first step in the process of creating the self-adaptive SCO is choosing the appropriate template from those ones that have been previously created. Once the template is loaded, we can distinguish three different areas on the screen (see Fig. 14). On the left, the template is shown and all of its objects (buttons, video-players, audio-players, etc.) can be mouse-selected in order to change

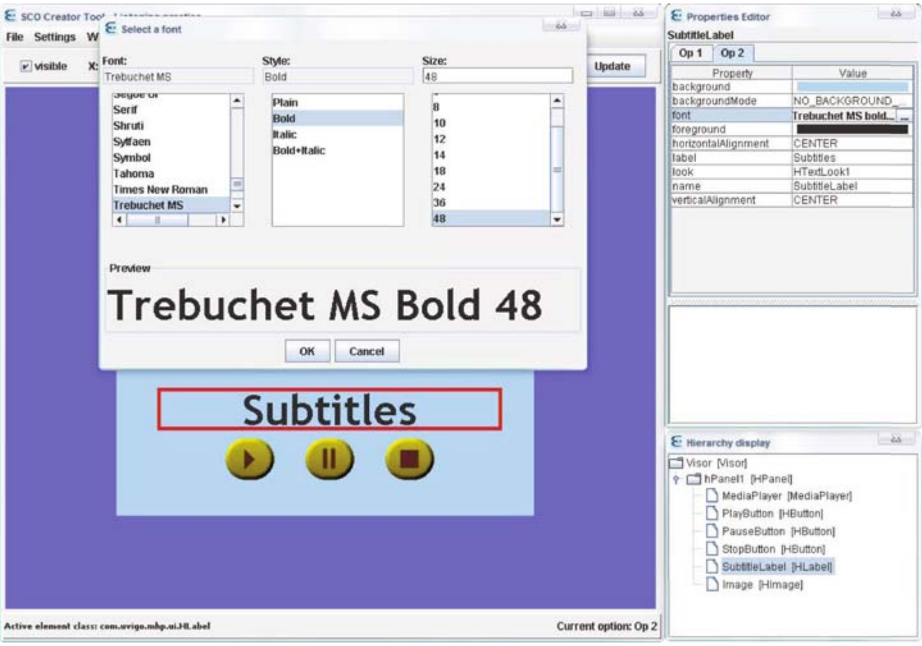


Fig. 14 The SCO creator tool: defining an option for people with eyesight difficulties

their properties (font style, background, name, etc.) by using the properties editor on the right. Other features, like size, position, depth and visibility of the objects can be changed by using the toolbar above the template (Fig. 15). Finally, on the bottom-right corner, it is possible to see the objects hierarchy which makes it easier to select objects that are contained in others.

Specifying different options To define self-adaptive SCOs, content creators should create different behaviors and change the objects' properties for each one according to the characteristics of the target user for whom the option is defined. For example, if the template is composed of a media player and a label to show the subtitles for the audio or video file offered in the player, one of the options may be designed for people with eyesight difficulties. So, the text font should be changed into a larger one (Fig. 14). All the properties that have been changed for a particular option are stored in the corresponding XML configuration file, ready to be used by the self-adaptive SCO to adopt the appropriate behavior.

Specifying the adaptation rules For each option, content creators should define the appropriate adaptation rules to provide SCOs with the information they need to self-adapt at runtime, according to the user's characteristics; i.e. to inform SCOs which configuration file to use at the personalization phase. In order to make this task easier, an adaptation rules editor has been designed (Fig. 15) with a very similar appearance to the one explained in the previous section for adaptation at activity level, for the sake of simplicity. By using this editor, content creators indicate the

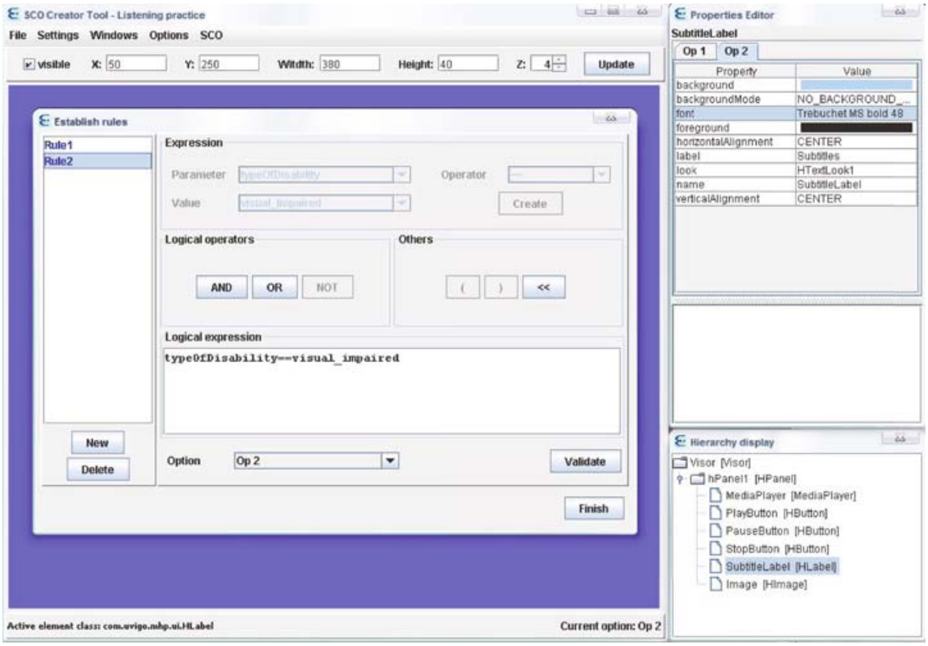


Fig. 15 The SCO creator tool: defining adaptation

characteristics of the target user for each option using logical expressions. In the example given above, option 2 is intended for visual-impaired users meanwhile option 1 is the default one. When clicking on the "Validate" button, the program converts the logical expression to XML code, so that creators do not need to know the syntax of the adaptation files.

Specifying metadata and building SCOs Content creators should specify the metadata to define the self-adaptive SCOs according to SCORM. The SCO Creator Tool provides a friendly area, which partially automates this monotonous task. Then, the SCO Creator tool definitively creates the self-adaptive SCO by generating the configuration file for each option and the adaptation file. Finally, it gathers in a JAR file (*Java ARchives*) the Java classes and all involved files together with the multimedia content—e.g. video, images or audio files—needed for the SCO to work properly.

Once a SCO has been created, it can be executed on any MHP-compliant machine where T-MAESTRO has been installed.[8]

[8] The reader can watch some video demos about the authoring tools presented in this article and adaptive courses behavior in an IDTV receiver at http://idtv.det.uvigo.es/proyectos/t-learning/en/index.html, section Demos.

6 T-MAESTRO: user and contents modeling

For personalization to be possible, it is essential to model two different aspects: contents and users. Only an appropriate modeling of both elements would support useful personalizations. So, in Section 6.1 we explain how TV and learning contents are characterized by using an ontological structure, while Section 6.2 focuses on how to store the user's preferences by using the semantic conceptualization of the TV and learning domains.

6.1 Contents modeling: the TV contents ontology and the SCORM ontology

In order to construct edutainment and entercation experiences, i.e. learning experiences integrating learning and TV contents, it is necessary to relate these contents. With this aim, we propose an ontological conceptualization of the world of contents via three main ontologies: one for the TV contents domain, one for the learning contents domain and one more for bridging the two domains. This structure of ontologies is shown in Fig. 4.

Regarding the TV domain, we use the TV ontology we have developed for the TV recommender AVATAR [11]. AVATAR was designed to filter the huge amount of TV contents that arrive in the transport stream by using semantic reasoning. So, according to the user's tastes (conveniently stored in the user's profile), AVATAR selects and recommends those TV programs that could be interesting for the user. With this aim, we have created an OWL [54] ontology storing a conceptualization of TV programs which follows the lines of the TV-Anytime specification [51]. TV-Anytime is an initiative of the most important actors in the multimedia contents industry that normalizes XML applications describing generic TV contents, specific instances of programs, user profiles, content segmentation information, and mechanisms to reference content regardless of location and broadcast time. To sum up, the core of this ontology of TV programs is a class hierarchy whose root element is the `TVContent`; and each instance of the ontology (corresponding to a TV content) will be related to its respective semantic characteristics through explicit properties (*hasActor*, *hasGenre*, *hasPlace*, etc.). Fig. 16 shows on its right the branch of this ontology with the parent classes for the movie "Under the Tuscan sun", as well as the branch that contains the instance of the main character of this movie, Diane Lane.

Regarding the learning domain, we have developed a SCORM ontology inspired by the one for IEEE Learning Object Metadata (LOM [21]) presented by J. Qin et al. [44] and available at [43]. We have extended this ontology in such a way that our ontology not only stores data belonging to LOM categories, but it also permits the creation of instances for every SCORM element and considers their interrelations. This ontology has then two main classes (Fig. 16, left): SCORM element, the parent class of all SCORM learning elements (asset, SCO, activity, content organization, content aggregation); and LOM category, which has one child class for each LOM category (in the figure, the only categories that are shown are educational and classification). More details about this SCORM ontology,[9] are explained in [45].

[9]Complete ontology available at http://tvdi.det.uvigo.es/proyectos/t-learning/SCORM_ontology/index.html.

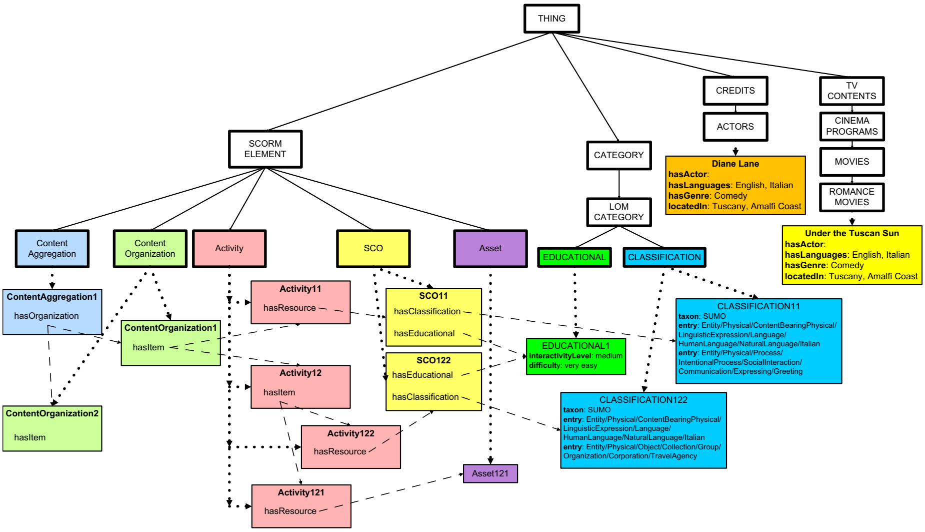


Fig. 16 Example of TV and educational ontologies

Finally, for the gateway ontology we use SUMO (*Suggested Upper Merged Ontology*) [35]. This ontology is being created by the IEEE Standard Upper Ontology Working Group to develop a standard upper ontology that promotes data interoperability, information search and retrieval, automated inferencing, and natural language processing. With this upper ontology, we can relate the semantic information stored in both TV and learning contents to build entercation and edutainment experiences like those explained in Section 2.2. For instance, there is a semantic relationship between the movie "Under the Tuscan sun" and the SCORM course "Starting with Italian" that can be found by using the upper ontology SUMO. The property *hasPlace* in the movie has the value "Tuscany" and the property *Language* has the value "Italian" in the course. Both instances, movie and course, can be related because the SUMO ontology maintains the following relationship: "Italian" is the official language of "Italy" and "Tuscany" is one of the regions of the same country.

6.2 User modeling

User modeling is essential for any personalization system to guide the adaptation process according to the user's preferences and interests. In order to be able to reason over the users' preferences and learning background, our methodology requires a formal representation of these characteristics, where descriptions of contents that the user likes and dislikes, as well as subjects that the user has and has not mastered, are provided. We consider then t-learning as a two-folded experience that contains both entertainment and educational elements. In fact, taking into account both aspects is what allows creating the integrated experiences we propose. Consequently, we suggest characterizing users according to these two aspects: as TV viewers and as learners.

Although different approaches for user modeling can be found in the literature [31], we prefer to preserve the ontological philosophy used for content modeling to facilitate the inference ability. So, we propose to use ontology-profiles to store user's tastes, interests and preferences. An ontology-profile maintains a set of classes and individuals belonging to a specific ontology (which supports the ontology-profile) and the user's opinion about them (the first approach to user modeling based on ontologies was proposed by Middleton in [32]). For T-MAESTRO, we consider that the most suitable option is to keep two different ontology-profiles: one storing the user's characteristics as a TV viewer (viewer ontology-profile) and another one storing the user's characteristics as a learner (learner ontology-profile).

The TV viewer profile is based on the TV ontology used for TV contents modeling. Each time the user watches a TV program, the branch of the ontology that contains the instance of this program is added to the user profile, as well as all the instances that are related to this program by means of properties. For example, if the user watches "Under the Tuscan sun", all the branch containing the instance of this program is added to his/her profile (as in the right side of Fig. 16), as well as the instances for the actors that appear (e.g. for Diane Lane, the instance of the class "Actor" corresponding to this actress is included), the director of the movie, etc. So, these are the instances that should be included in the user profile, but the user can like or dislike these programs. The user's opinion positive or negative, is stored by using the index DOI (*Degree of Interest*) [9], a numerical value (in the interval [−1,1]) that reflects the level of interest of the user in the program. This value can be established in an reactive or proactive manner. The former, called Index Of Viewing (IOV) entails that the DOI is deduced from the user's behavior for a specific class or element in the ontology, computing the relation between the time that the user invests in watching a program and the its total time-length. The latter, named Index of Feedback (IOF), is based on an active participation of the user: he/she must give his/her opinion by voting among different options: very interesting (1), interesting (0.5), not very interesting (−0.5) or not interesting at all (−1); if the user does not provide this information, this value is established as 0.75 if the user accepts the TV program and −0.75 if he/she rejects it. Joining both kinds of information, the feedback agent deduces which is the DOI linked to a particular program (p) in the user profile, in the following way:

$$DOI(p) = \begin{cases} IOV(p) \cdot IOF(p) & \text{if the user accepts the program } p \\ IOF(p) & \text{otherwise} \end{cases} \quad (1)$$

The student profile, in turn, is based on the SCORM ontology, used for pedagogical contents modeling. The process of creation and the calculation method for the DOI is the same as the one explained for the TV viewer profile, with the difference that we include instances of SCORM elements studied by the user and the data from the LOM categories associated with them. But, in this profile, the DOI does not give us enough information. In an academic perspective, it is important to know also the knowledge degree, i.e. the performance of the student in the concrete learning element. We refer to this value as Degree of Knowledge (DOK) that belongs to the interval [−1,1]. This value is obtained according to SCORM rules: in the case of an asset, there is no way to determine this value (because assets cannot communicate with LMSs) so, its DOK is −1 if the user has rejected it and 1 if he/she has accepted it; in the case of SCOs, they can communicate this value to the LMS by means of the following elements from SCORM Data Model: scaled passing score (SPS) and scaled score (SS) (both provide values in the interval [−1,1]), that indicate the score required to master the SCO and the performance of the learner, respectively. The DOK for a particular SCO *s* is then calculated as:

$$DOK(s) = SS(s) \cdot \left(1 + SPS(s)\right) \tag{2}$$

If the SCO does not communicate these values, the same criteria as for the assets are used.

For higher level SCORM learning elements (i.e. activities, content organizations and content aggregations) the SCORM rules to rollup the values for the objectives from the values offered by SCOs and assets are used, as explained in the sequencing rules of the particular learning element.

For the sake of efficiency, only references to the instances of the programs and learning elements the user has watched are stored on the client side, since storing all the classes and instances in the user profile would occupy too much memory space. On the server side, the complete ontology with all of the instances is maintained and updated and it can be consulted by means of a predefined interface.

One of the problems of user modeling is the initialization of the user profile when he/she first access the system. One of the solutions is offering the viewer a detailed form where he/she can express his/her preferences about every type of TV contents, and all possible subjects for learning. However, this solution is not appropriate for passive users like TV ones. In this approach, ontology-stereotypes are used for this purpose. An ontology-stereotype is a generalization of the concept of ontology profile which stores the common likes and dislikes of a group of interest. The user, when he/she logs on the system for the first time, is presented a simple form where he/she is asked about his/her age, educational level, educational orientation, learning preferences (he/she is asked to choose a couple of subjects of interest among the available ones), as well as the TV genres that he/she likes and dislikes more. With this information, the system generates an initial ontology profile, called ontology-stereotype created from the intersection of the profiles of the *n* closest neighbors, i.e. those who have their own ontology profile (not the stereotype one) and have given the same answers than the target user. Besides, these stereotypes are also used by content providers as a guide to create relationships between contents. In this manner the core contents are complemented with additional contents taking into account the more common stereotypes.

Finally, we have to take into account the fact that TV is a social medium: TV is often watched on the living room with some other people. So, a problem arises when selecting or personalizing contents for a group of users. This problem has already been identified in the field of IDTV [20, 29] and several strategies have been proposed: the average, that rates a new content as the average of the rates of individual users; the last misery, that assigns the lowest of the rates; the most pleasure, that assigns the highest of the rates; the average without misery, that calculates the average rate excluding the lowest one; the fairness, that chooses the element that one of the user likes more, discarding this user for the following choice; and the most respected person strategy, that chooses only the elements that the most respected person wants to watch, using the rest of opinions to decide among similarly rated items.

Our solution consists in constructing a group ontology-profile using a mathematical union of the ontology profiles of all the viewers implicated. To calculate the DOI for each element of the new ontology-profile, we use the average strategy, assigning the average value of the DOIs of all the viewers. When a viewer does not have an element in his/her profile, he/she is assigned DOI=0. Concerning DOK, the same strategy is not appropriate since this would lead to provide some viewers with learning elements that they do not have enough knowledge to study. To calculate the DOK we use then the least misery strategy, assigning DOK=0 to a user that does not have the target element in his/her profile.

7 T-MAESTRO: functional stages

At the receiver side, T-MAESTRO obtains the most adequate entercation and/or edutainment experiences for the final user from the contents carried by the IDTV transport stream. We assume that this transport stream contains pedagogical and entertainment contents by means of: traditional channels, thematic channels, channels exclusively dedicated to educational aims, etc. Besides, we assume that IDTV broadcasters have previously established a network interconnecting the contents according to their subject matter for the different stereotypes profiles (Section 3.3). Fig. 17 shows the different stages needed for T-MAESTRO to create the proposed learning experiences.

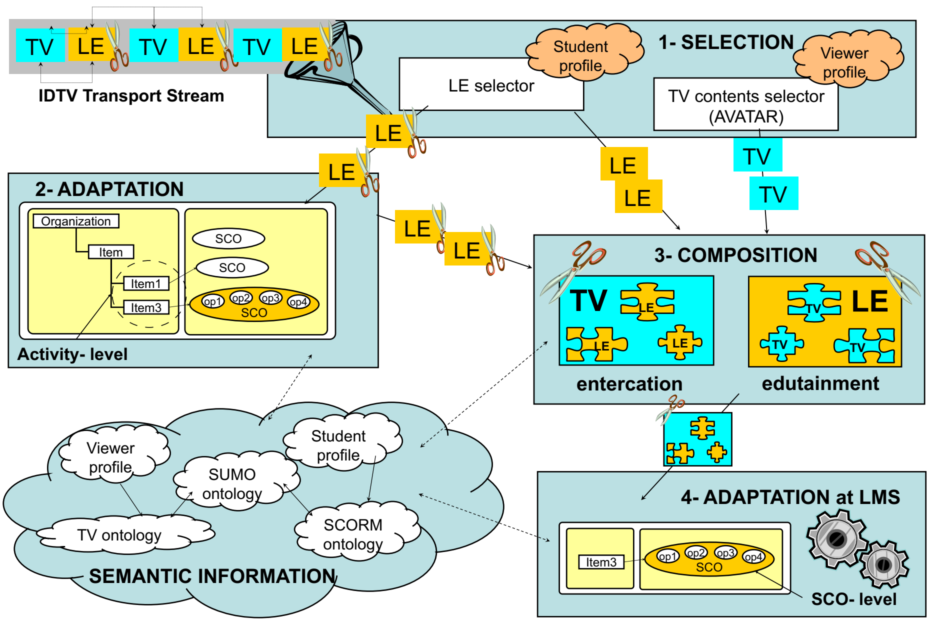


Fig. 17 T-MAESTRO stages: from IDTV contents to entercation and/or edutainment experiences

Selection In this phase, those contents that are appropriate for the user's preferences stored in his/her ontology-profile are filtered. The selection stage is divided into two parallel sub-stages. On the one hand, those contents labeled according to the TV-Anytime specification are filtered by AVATAR. This system is a parallel work of our research group and it is out of the scope of this current proposal, since it works independently. However, we summarize next its reasoning process because we reuse it for educational elements (the whole reasoning process is explained in [9]). AVATAR's recommendation strategy combines content-based methods and collaborative filtering[10] enhancing them with semantic inference capabilities. This hybrid strategy has two phases. Firstly, a content-based phase is applied, in which the approach assesses if the target content is appropriate for the user, by considering their personal preferences, computing the semantic similarity between the target content and the programs stored in the user's profile. The semantic similarity has two different components: the hierarchical semantic similarity, that depends only on the position of the classes they belong to in the content hierarchy; and the inferential similarity, which is based on discovering implicit relations between the compared programs (programs that share semantic characteristics such as cast, genres, places, topics, etc). The second phase is based on collaborative filtering, where the system predicts the level of interest of the user with respect to the target content based on his/her neighbors' preferences. A particular characteristic of this last phase is that it not only takes into account the neighbors that have this content in their profile, but also those ones that don't, inferring in this case the DOI by means of the semantic similarity obtained in the previous phase.

On the other hand, those contents labeled according to the SCORM specification are filtered by the learning objects (LE) selector. Again, the same strategy used for TV contents is applied, with the particularity that not only the DOI should be taken into account, but also the DOK. To be recommended, a learning element should not only be semantically similar with respect to the DOI but also with respect to the DOK. This approach takes into account the contents that the user has studied to recommend him/her new contents, in order to provide him/her with a coherent learning path, in a similar way as done by systems that use the *electronic road* metaphor, where documents encountered during the interaction of the learner with the system are not considered to be unrelated from each other, but distinct steps of the his/her path [52].

It is worth noting that the same IDTV content might be labeled with both TV-Anytime and SCORM metadata; for instance, a documentary about the Mesopotamian civilization could be only a TV documentary or a learning element in a wider course about ancient history. Anyway, these contents are doubly processed by AVATAR and the LE selector. Consequently, when finalizing the selection process, those elements that are not appropriate for the student have already been discarded.

[10]Content-based methods and collaborative filtering are the recommending strategies that have achieve outstanding popularity. The former recommends to users contents similar to those they have watched in the past, whereas the latter suggests the users contens appealing to viewers with similar preferences.

Adaptation Adaptive SCORM courses are tailored at activity-level according to the adaptation parameters obtained from the user's ontology-profile by applying inference rules. Thus, the number and sequence of pedagogical activities are chosen among the alternatives specified in the adaptation file to be as faithful as possible to the user's preferences, as already explained in Section 4.2.

Composition In this stage, educational experiences, both entercation and edutainment, are built from the selected and adapted contents. Although semantical relationships between these contents were established by the IDTV broadcasters, T-MAESTRO has to filter those links to offer the student only the relevant ones (according to his/her preferences and knowledge). Depending on the receiver's computing power this filtering can be performed in two different ways: the simplest one is comparing the targeting information of TV-anytime metadata that IDTV broadcasters have included, with the characteristics provided by the user in the first login; or, for more complex receivers computing the semantic similarity—as explained in the selection phase—between the additional contents and the contents included in the user's profile.

Run-time After the selection, adaptation and composition processes, there are different entercation and edutainment experiences ready to be used for the viewer. Consequently, there should be a suitable mechanism for users to know that these experiences are ready and how to access them. With this aim, in our proposal we have defined two different mechanisms: a reactive solution and a proactive one. In the former, the user takes the initiative and asks the system for the contents it has previously prepared (edutainment). In this case, the t-student has a simple interface to which he/she can interact very easily by using the remote control. In the latter, the system takes the initiative and displays a small spot in the bottom-right section of the screen indicating that there are additional contents related to the subject matter of the program he/she is watching (entercation). The user shows his/her interest by selecting the option in the remote control.

Finally, if an additional pedagogical content is selected, the final adaptation phase takes place: adaptation at SCO-level at runtime within the LMS subsystem, which is in charge of receiving the contents and showing them to the viewer. The self-adaptive SCOs instantiate the options provided in the adaptation file according to the user's preferences just before being shown to him/her, as already explained in Section 4.3.2.

8 Evaluation

This system has been presented, jointly with other proposals, within an *Information Technology for European Advancement* (ITEA) project, called Passepartout.[11] This project focuses on the convergence of digital systems and applications in home media-centers matching the vision of industries, institutions and government partners. The goal is to make a step toward ambient intelligence through mass

[11] Passepartout website: http://www.citi.tudor.lu/passepartout.

Table 1 Evaluation of the requirements of the system

Requirements	Achieved by	Improvements
Personalization of learning	Selection of elements and adaptation of LEs	Finer granularity for the options of Self-Adaptive SCOs and Parsing LOM Metadata
Integration of TV programs and learning elements	*Entercation* LEs fulfil the user's curiosity concerning the themes dealt with in TV programs. *Edutainment* TV programs complement LEs to make the learning process easier.	Establishment of relationships between LEs and segments of the content.
Support in the creation of adaptive LEs	SCOCreator Tool and A-SCORM Course Creator	Inclusion of advanced creation features, such as copy/paste, undo and version control
Discovering of relationships between contents	*Broadcasters* Using AVATAR's reasoning algorithms	*Receivers* These algorithms are very heavy for receivers. Lighter ones that use folksonomies are being studied.

personalization of TV contents so that home media-centers move beyond current set-top boxes and PVR (*Personal Video Recorder*) players using MPEG-2 technology, to true mass-customization devices for family entertainment. The vision of the project is the "Maxima scenario" (the Maxima's family) where digital TV contents are used to enrich the lives of a family. As part of this vision, *infotainment* is introduced as using TV for the family to participate in society and not just to passively consume TV contents. Inside the infotainment approach, edutainment/entercation experiences play the role of educational *infotainers*. The Passepartout project has already finished and final testing meeting has allowed us to let other partners experience the personalized t-learning framework we have designed and proposed in this article.[12]

During the testing of this project, we have noticed that the recommendation algorithms used in the composition phase, while accurate, are very time consuming, for this reason they have to be performed on remote servers rather than in the user's STB. For this reason, we are now studying the possibility of applying Web 2.0 technologies to this field, particularly *folksonomies*, to create a lighter reasoning strategy. The term folksonomy has been first coined by T. Vander Wal[13] to describe the taxonomy-like structures that emerge from the method of collaboratively creating and managing tags to annotate and categorize content. We are now working on the definition of a reasoning method based on folksonomies (several works along this line have been already proposed in [36, 50]) that computes the similarity of the tags of the target content and the tags of those contents available in the user's profile, weighted by DOI and DOK indexes.

[12]In http://tvdi.det.uvigo.es/proyectos/t-learning/en/demos.html there are some videos showing the current state of the system.

[13]http://www.vanderwal.net/random/entrysel.php?blog=1750.

Apart from efficiency issues, and taking into account that the reasoning algorithms have already been evaluated in [10], we have summarized in Table 1 how the requirements of the system exposed in Section 3 have been addressed. Moreover, it is also important to evaluate the usability of the learning experiences. For this reason, we have carried out some trials in our lab with students of the University of Vigo. As a consequence, we have obtained some feedback we have applied to improve the system. These improvements are mainly related to usability and, in general, the testing users consider the system useful and attractive. However, this evaluation process does not represent a real environment. For a proper evaluation, users should be at home, and t-learning experiences should be executed on their STBs, with the additional inconvenience that most of the STBs sold in Spain are only compatible with the DVB-T specification [14] and are not able to execute MHP applications, so, our proposal cannot be tested in such devices. In the near future, we will solve these constraints since we are involved in a project with a local cable company, which will permit us to test t-learning experiences with different types of real users: elder people, housewives, children, etc.

9 Conclusions

In this paper we have introduced the concept of entercation experiences, where TV programs are enriched with courses or learning elements related to their subject matter, to attract viewers toward education. Entercation, with this conception, supplements the idea of edutainment experiences, where courses or learning elements are enriched with TV programs (or fragments) to make the pedagogical experience more attractive to t-learners. Anyway, these courses or learning elements which are enriched with TV programs (edutainment) or which are used to enrich TV contents (entercation), must be especially created for the new medium: the Interactive Digital TV. Consequently, they should be media-driven and mainly focused on multimedia contents. Additionally, and with the aim of engaging t-learners, we propose to personalize both kinds of educational experiences. Thus, only TV contents related to the user's tastes are selected to be used in the t-learning experiences. Besides, the learning elements (SCOs or whole courses) are also tailored to the user's interests and learning background. Finally, it is at the receiver side where both selection and adaptation take place.

In this paper, we have exposed an appropriate architecture to support the creation of these new personalized educational experiences combining pedagogical and TV contents. On the one hand, we have developed an authoring tool which allows course creators to design and build adaptive pedagogical contents. On the other hand, we have also designed an intelligent tutoring system, named T-MAESTRO, which selects, adapts and composes both learning elements and TV contents to provide entercation and edutainment experiences to the final user.

The authoring tool we have developed, *A-SCORM Course Creator Tool*, provides a friendly environment for course creators to build adaptive pedagogical contents. All adaptation options can be specified at design time because of our extension to the ADL SCORM standard. The adaptation takes place at two different levels: at SCO and activity levels. The adaptation at SCO level allows SCOs to change their behavior according to adaptation parameters deduced from the user profile.

The adaptation at activity level permits to establish different ways to achieve the objectives of an activity depending on the values of the adaptation parameters for the user who studies the course.

Finally, and although these adaptive contents are properly understood by T-MAESTRO at the receiver side, our SCORM extension is totally compatible with other SCORM learning management systems which do not understand the proposed extensions. Thus, self-adaptive SCOs would show their default options and adaptivity at activity level would be ignored, so all the activities in the activity tree would be shown. Furthermore, any SCORM-conformant LMS can be used for SCO-level, because it does not need additional intelligence (it only has to look up into a bigger data model). At activity-level, this coherence with previous SCORM-conformant systems is possible due to the encapsulation of adaptation information and the provision of SCOs with a default behavior.

10 Future lines of research

Nowadays, our edutainment experiences consist of linking educational contents to TV programs, i.e. they consist in offering these learning elements to the viewer, who finally decides to follow them or not. However, as important as selecting these extra contents is choosing the most appropriate moment to give these offerings to the viewer. To do so, it is essential to handle semantic and structural information of the TV program. Although TV-Anytime is the proposal we have been managing, it describes a rather limited content structure, since it defines segments only as temporal intervals within an audiovisual stream, i.e. a continuous fragment of a program. MPEG-7 (*Multimedia Content Description Interface standard*) [22] offers wider possibilities and so, a more powerful description scheme. It allows the definition of many different types of segments, not only temporal intervals, as well as the creation of segment hierarchies. Consequently, our ongoing work is devoted to using a subset of the metadata defined in MPEG-7 to label TV programs and to be able to identify which is the best option to give a learning offering.

Concerning labelling, we have supposed in this article that content creators provide the description for the contents in detail, since they are the ones that know the content best. However, it can be argued that this fact makes the project lack of feasibility: on the one hand, content creators are not likely to label the programs if it does not bring them economical benefits; on the other hand, even if they label them, they would describe only those characteristics that would bring such benefits.

For this reason, our approach can be greatly enhanced if the description of the programs provided by the content creators is complemented with additional labeling mechanisms, like collaborative and automatic tagging. The former is an emerging technology where many users add metadata in the form of keywords to shared content, so that they cannot only categorize information for themselves, they can also browse the information categorized by others [19].

Automatic tagging, in turn, consists in extracting information directly from the video by means of computerized methods. In this direction we have developed an application that extracts information related to the events that take place in sportive matches from the web pages that describe them (such as NBA play-by-play, http://www.nba.com/games/20061208/TORCHI/playbyplay.html) [46] and we are working on an interface to allow viewers to collaboratively add tags to TV programs and educational contents.

Another important issue is the exportability of this proposal to other media. We have already introduced in the beginning of this article the concept of m-learning, where learning takes place in mobile devices such as phones or PDAs. This proposal could also be exported to the Internet area, creating learning experiences using videos from TV channels that broadcast through Internet (such as http://wwitv.com), web pages devoted to offer video (e.g. http://www.youtube.com) and P2PTV applications, peer-to-peer software applications designed to redistribute video streams or files on a p2p network, typically TV stations across the world (such as PPStream, www.ppstream.com). These learning experiences could take advantage of the huge amount of learning contents already developed for web. To export these experiences to other environments, it is very important to take into account the particularities of every medium. If we want to create learning content that can be studied in different platforms we need to provide terminal adaptivity [15] in order for them to be correctly shown independently of the terminal device.

Finally, we are also working in reducing the computational cost of personalizing educational experiences by taking advantage of the collaborative environment provided by ATLAS [38]. These personalization efforts are currently shared between the IDTV broadcaster (which uses stereotypes) and the IDTV receiver (which uses personal profiles). However, having a collaborative environment, which promotes virtual learning communities, the IDTV receivers in the same virtual community could also share the adaptation tasks, because they are also assumed to share many characteristics in their personal profiles. Thus, the efforts of personalizing the same course should be divided between their receiver set-top boxes, instead of being done repeatedly and separately by each one.

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