A Heritage Dissemination Approach for the Production and Maintenance of Repositories of Learning Objects[1]

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Abstract. In this paper we propose an approach to the production and maintenance of repositories of learning objects that is based in our previous experiences with the virtualization of two academic museums at Complutense University of Madrid. For this purpose we have adapted the specific learning object model and the incremental and evolutionary methodology used in these virtualization experiences. As in those cases the main goal was to exploit the pedagogical value and to *disseminate* the cultural heritage of the museums, in the approach presented in this paper the main goal is to *disseminate* the preexisting learning materials, e.g. exercises, lecture notes, surveys, lab manuals, etc, used by instructors in their daily work. As a result of this virtualization process these materials are empowered by the learning object paradigm: they can be created, stored, located and reused by instructors and students in new collaborative and unanticipated ways in order to achieve their personalized learning objectives. The approach is illustrated in the domain of *language processors*.

Keywords: Learning Objects, Repositories, Authoring, Virtual Objects, Education in Language Processors

1 Introduction

The learning object paradigm is a key aspect in modern e-learning technology [8,11]. This paradigm promotes the provision of basic auto-contained chunks of learning contents with well-defined pedagogical goals that can be assembled to create more complex objects and reused in many different learning scenarios. While the paradigm itself seems promising, its use has been defeated in practice. In our opinion, the primary cause of this lack of practical acceptance is due to the effort required by the paradigm shift. Typical instructors are already using text books, well-structured lecture notes and other very valuable supportive learning materials, and they are skeptical about the advantages of changing all this well embodied corpus of knowledge for collections of reusable learning objects. In this paper we propose that the process of creating learning objects should be viewed as one of *dissemination* of those preexisting learning materials instead of one of *renovation* to completely new ones.

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We have realized the advantages of viewing the production and maintenance of learning objects as a dissemination activity in a domain that is naturally concerned with preservation of the cultural heritage: the domain of the academic museums. For this purpose we undertook the production and maintenance of two repositories of learning objects associated with two academic museums at Complutense University of Madrid (Spain): the *Antonio Ballesteros* museum of archaeological and ethnographical material maintained at the Department of American History II, and the *José García Santesmases* museum, a museum of history of computing located at the Computer Science School [7]. In these experiences we used a very flexible model of learning object (the *virtual object* model), together with a very flexible and dynamic virtualization methodology. The approach was formerly applied to the *Antonio Ballesteros* museum, whose repository contains currently more than 1500 objects, and where the approach has shown its usefulness from an educational point of view [10]. With the virtualization of the *José García Santesmases* museum we realized as the approach could be applied to other similar domains. The resulting repository currently has more than 100 objects, which correspond with the pieces exhibited in the museum at the Computer Science School.

In this paper we defend that the materials managed by expert instructors, who many times conjugate a strong formative vocation with an intensive research activity, should be viewed as a valuable heritage to be preserved and disseminated. For this purpose we propose the application of the aforementioned virtual object model and virtualization method. We illustrate the resulting approach in the domain of *language processors*, a domain related with the definition of programming languages and the construction of the processors (i.e. compilers or interpreters) for these languages.

The structure of the paper is as follows. In section 2 we summarize the main concepts behind the virtual object model, as well as the virtualization method followed in the museum experiences. In section 3 we translate these results to the production and maintenance of learning objects from the pre-existing learning resources managed by instructors. In section 4 we exemplify the approach in the domain of language processors. Finally, in section 5 we give some conclusions and outline some lines of future work.

2 The Virtual Object Model and the Virtualization Method

In this section we summarize the Virtual Object (VO) model used in our experiences with the academic museums (subsection 2.1), as well as the virtualization method used (subsection 2.2). These aspects are further discussed in [7,10].

2.1 The Virtual Object Model

The Virtual Object (VO) model can be related to the Stephen Downes proposal of changing the paradigm of learning objects to resources and resource profiles [2], but instead of focus on the description of one specific resource, the VO model focus its attention on the set of resources that represent, or are closely related to, one specific object (physical or conceptual) and on the sets of attribute-value pairs that describe the data and the meta-data of the object. In essence a VO is a chunk of (Fig. 1a):

- A set of attribute – value pairs called the *data* of the object. These data represent all the features of the object considered useful for its scientific study (e.g. the *weight* and the *dimensions* of a piece of pottery or the *language* and the *literary style* of a document).
- A set of attribute – value pairs called the *metadata* of the object. These attributes represents features useful for the description and the classification of the object from a pedagogical point of view. Metadata is taken from the IEEE LTSC Learning Object Metadata (LOM) [4]. Examples of metadata can be the *author*, the *version number* or the *classification* of the object in one or several taxonomies.
- The set of *resources (digital files)* and a third set of attribute - value pairs describing these resources and its relation to the object. Resources are further categorized into three different types. *Own resources* are a set of multimedia archives (e.g. a set of photographs of a pottery vessel or the raw and the structured text of a document). *Foreign* resources are references to resources owned by other VOs (e.g. a text describing the different aspects of the culture that manufactured the pottery vessel or a text with the biography of the document's author). Finally, *VO resources* are references to other VOs (e.g. a VO associated with another piece discovered in the same excavation or a VO of another document written by the same author).

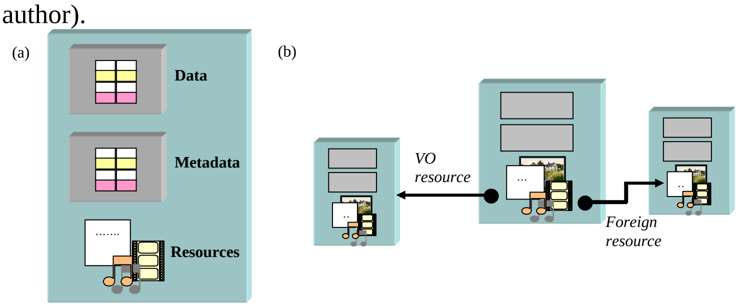

Fig. 1. (a) VO model; (b) VOs can be linked together using foreign and VO resources.

Foreign and VO resources allows for the establishment of basic relationships between VOs and the construction of more complex VOs by aggregating simpler ones. This leads to a first *ad hoc* organization of a repository of VOs in networks of interrelated VOs (Fig. 1b). Besides, metadata can be used to define other organizations. For this purpose, the model strongly encourages the use of the LOM `classification` element for classifying the VOs in one or several taxonomies.

2.2 The Virtualization Method

In our experiences we have maintained the VO model as simple and as flexible as possible. Indeed, we have allowed the evolution of the model in three different dimensions:

- The *classification dimension*. The taxonomies used to classify the objects are not given a priori, but they are dynamically constructed conforming more and more VOs are added to the repository (Fig. 2). Indeed, if a VO is classified in a non-existing path, this path is readily added to the existing taxonomies, initiating a new one if required.

- The *data dimension*. During our experiences we have maintained the data structure of VOs open. In this way, authors can add new data attribute – value pairs when required.
- The *resource dimension*. The set of possible resources is also kept open. When a VO is created the resources required can be readily chosen.

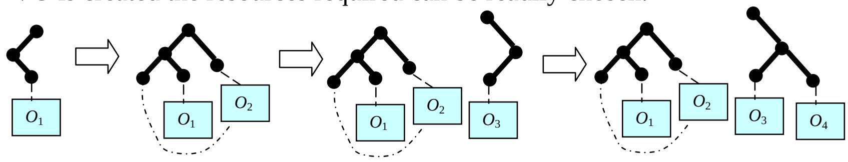

Fig. 2. VOs can be classified in taxonomies that are dynamically constructed conforming new objects are added to the repository.

This virtualization method allows for a high degree of flexibility, which makes it especially well suited for supporting collaborative, author-driven, incremental and evolutionary approaches to the production of learning objects, such as we have realized in our experiences with the virtualization of the aforementioned museums. Indeed, in these scenarios the first stages of the virtualization process were devoted to produce VO digital counterparts of the physical objects included in the museums. Later stages produced higher-order VOs of more abstract nature (e.g. containing glossaries of common terms, or related with different aspects of the culture of an excavation; see [10] for more details). During the successive stages the classification taxonomies were also extended, refined, and corrected to solve inconsistencies and redundancies. This flexibility can be also exploited in the virtualization process of the pre-existing learning materials managed by the instructors in different learning domains, as described in the following sections.

3 Virtualizing the Instructional Heritage

In virtualizing the learning materials managed by an instructor according the principles exposed in the previous section it is needed to identify a counterpart to the physical objects arising in the museums. Suitable candidates are case studies [6], and problems proposed by the instructor to their students.

During the virtualization process the instructor can adopt a *problem – based* strategy [3]. She/he can choose representative case studies or problems from her/his teaching materials, and add them to the repository as VOs. Among the resources of the corresponding VOs the instructor will provide the corresponding problem's *enunciate* and *solution*, together with all the complementary resources (e.g. images associated with the explicative schemas and supportive materials) referred from these elements. This strategy leads to the following typical aggregation patterns for the VOs in the repository (Fig. 3):

- The VO associated with a problem or case study makes reference to other VOs explaining different aspects of the solution (Fig. 3a). An example of these new VOs is given by the glossary of terms mentioned in the previous section.
- Such theoretical – oriented VOs can be refined in a top-down fashion into more elementary VOs (Fig. 3b).

- Some problems can be in turn stated as the elaboration of surveys about a particular subject, and their solutions can make reference to pre-existing VOs of many different nature as illustrative aspects or examples (the case with the cultural study of an excavation cited in the previous section; see Fig. 3c).
- Any of the aforementioned VOs can make reference to foreign resources of other objects (e.g. a diagram, a blueprint, etc.) in order to reuse such a resource (Fig. 3d).

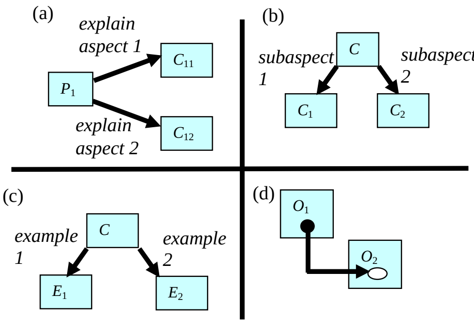

Fig. 3. Different aggregation patterns: (a) a problem-oriented VO refers to theoretical-oriented VOs explaining different aspects of the solution; (b) a VO is further refined in several sub-aspects; (c) a VO representing a survey about a subject makes reference to other VOs representing some illustrative aspects or examples; (d) a VO makes reference to a foreign resource.

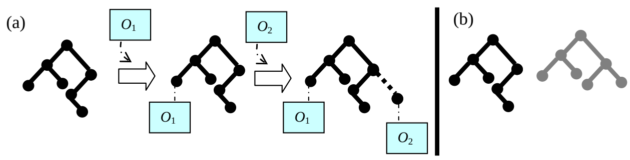

Fig. 4. (a) Instructors can propose a initial taxonomy that is refined if required; (b) The taxonomies of different instructors can co-exist.

All of these are virtualization behaviors that have been observed in our experiences in the domain of the academic museums. Still other patterns of virtualization could be applied depending on the judgment of the instructors and depending on the concrete nature of the learning domain.

The virtualization process also can take advantage of the dynamic nature of the classification taxonomies. For this purpose, the instructor can establish an initial taxonomy based on his/her particular understanding of the domain's structure (Fig. 4a). This taxonomy can be subsequently extended and/or modified if required. Besides, taxonomies can be used as mediation mechanisms by instructors who collaborate in the production of a common repository in a domain. Indeed, an instructor can explore the other's taxonomy in order to discover interesting VOs, and she/he can subsequently re-classify these VOs in her/his own taxonomy (Fig. 4b).

4 An Example: The Domain of Language Processors

The learning domain of language processors has to do with the systematic definition of programming languages and with the systematic construction of their processors (i.e. compilers and interpreters) [1].Our interest in this domain is twice. As educators who are currently teaching this subject at Complutense University, we would like to incrementally produce a body of valuable learning material able to support a more constructive approach for our students learning this subject. As computer science researchers we are interested in testing the learning object paradigm, and more precisely the VO model, in this domain. In this section we use our own experience as instructors in this domain to illustrate the virtualization phenomena discussed in the previous section. The identified aggregation patterns are illustrated in subsection 4.1. Subsection 4.2 in turn goes on initial taxonomies and taxonomy extensions.

4.1 Aggregation patterns

In order to allow our students to figure out the internal behavior of a language processor we propose them several case studies regarding the processing of sentences belonging to simple programming languages. The contents of all the VOs that arises can be recovered doing a little of *archeology* in our lecture notes.

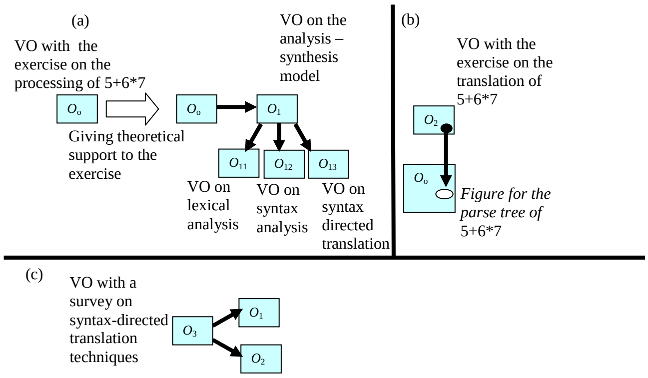

Fig. 5. (a) Adding an exercise about the evaluation of an expression; (b) adding an exercise about the translation to machine code of such an expression; (c) adding a VO with a survey about the application of syntax-directed translation techniques.

For an introductory purpose we use a simple *analysis – synthesis* model [1]. According with this model, processing starts with the tokenization of the phrase during lexical analysis. Then, the sequence of tokens is parsed onto a syntax tree that exposes the phrase's structure. Finally, this tree is used to synthesize a suitable translation. In Fig. 5a we outline the effect of introducing one of these exercises as a VO (e.g. one regarding to the processing of the expression `5+6*7` to obtain its value). The addition of this VO also supposes the addition of a thematic VO about the *analysis – synthesis* model. This VO can be further refined in a VO with an introduction on lexical analysis, another one with an introduction on syntax analysis, and a third one introducing syntax – directed translation.

In the solution of a new exercise regarding the previous expression (e.g. by proposing the translation of `5+6*7` to the machine code of an stack-based virtual machine) it could be possible to reuse some of the schemas produced in the previous case (e.g. the parse tree). In addition, a new VO regarding stack machines can be added, and the thematic support mentioned above can be refined accordingly (Fig. 5b).

Finally, in writing a survey about the general principles of the syntax – directed translation, it is possible to make reference to the previously introduced cases, since evaluation of an expression and code generation for such an expression are both concrete examples of applying the technique (Fig. 5c).

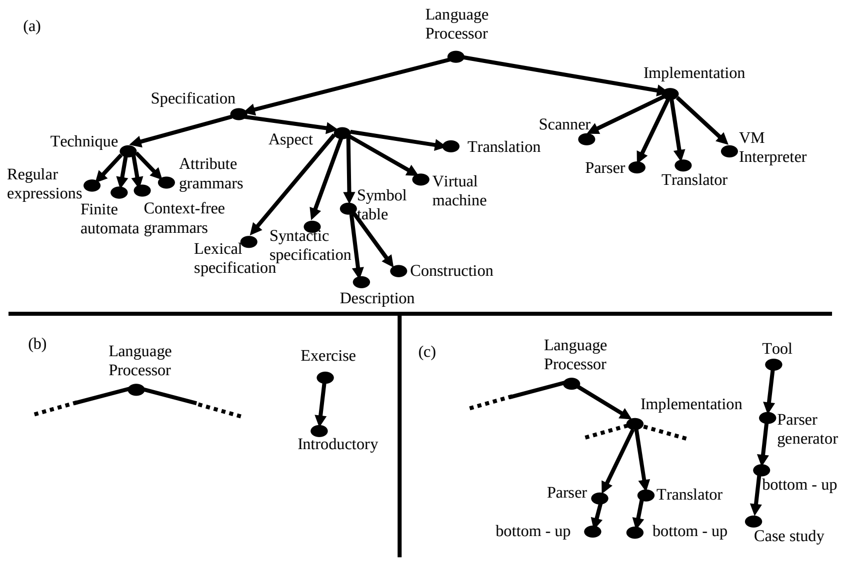

Fig. 6. (a) An initial taxonomy for the domain of language processors; (b) a refinement for an alternative exercise categorization; (c) another refinement regarding processor construction tools and different types of parser and translator.

4.2 An Initial taxonomy and some taxonomy refinements

In proposing an initial taxonomy for the domain of language processors we can use the rhetorical structure that we follow in teaching this course. Indeed, we promote a clear separation between *specification* and *implementation* aspects. In Fig. 6a we show a simplified initial taxonomy.

Conforming new VOs are added to the repository the initial taxonomy can evolve. For instance, when the VO associated with the exercises on the expression evaluation is added, a new root category can be added in order to group all the case studies together, and to further classify such case studies in terms of the degree of difficulty (Fig. 6b). A more interesting example arises with the inclusion of a case study about YACC [5]: a new category for grouping VOs related with development *tools* is created, and also the implementation hierarchy is refined to deal with distinguished types of parser and translators (Fig. 6c).

5 Conclusions and Future Work

In this paper we have proposed an approach to the production and maintenance of repositories of learning objects based on the model and the method followed in the virtualization of two academic museums at Complutense University of Madrid. Instead of being intended as a transfer one, the approach let instructors find new ways of using their materials, since they can adopt a problem-based approach and to incrementally use the different sorts of materials to support the proposed case studies. The approach allows several co-existing points of views that are concretized in different classification taxonomies. Therefore different instructors can collaborate in the same virtualization experience, reusing material produced by others, and even the same instructor can catalogue the same material in many different forms.

Next step in the project is to complete the repository related with language processors and to test it with our students at Complutense University. As a future work we want to develop a general system based in the virtualization principles exposed in this paper that supersede to the currently existing ones [7] and also to apply it to the related field of computational linguistics. We are planning to further use our document-oriented approach for this purpose [9].

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