An Integrated Approach to Learning Object Sequencing

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Abstract

The use of learning objects (LOs) to support learning processes is considered a key factor in the deployment of e-learning frameworks. Although their discrete and self-contained nature offers many advantages LOs have presented courseware designers with two fundamental issues. The first issue concerns the adequate identification of the learning objects and the second relates to their integration into a suitable learning programme. This paper is concerned with the presentation of a framework that addresses and reconciles these requirements by capitalising on the metadata of the learning objects and on the profiles of the learners. The learning process is mediated by a core component, a learning management system (LMS) that, through a registry, accesses the metadata of the learning objects published by providers and acts as a repository of metadata. In addition, it enables learners to construct learning paths (LP) from a set of relevant LOs in accordance with their profile. The LMS can also generate automatically a learning path on behalf of a learner and determine the schedule of the learning process. The implementation of the framework takes advantage of the flexibility of Web Services.

Keywords: Learning path, profile, object lifecycle

1. Introduction

The deployment of many e-learning programmes is facilitated by the role that learning objects (LOs) are playing in supporting the learning processes. Their appeal is due largely to their discrete and self-contained nature and their ability to be re-purposed in different educational contexts [1]. Their potential for mediating knowledge effectively is one of the critical factors behind the success of many e-learning initiatives [2].

LOs are now available in several repositories, where they can be accessed to address various educational needs [3]. Although the search and discovery for relevant LOs is eased by the provision of metadata, repositories are still considered difficult to navigate. The search for LOs is further compounded by the fact that they are usually designed for a generic learner who has to filter manually several LOs before selecting a suitable one.

The development and deployment of a learning object defines a lifecycle [4] in which the most significant stages include development and publication, availability in repositories and integration into e-learning programmes. Once part of the learning process the LO can ultimately be used by learners. Two main considerations emerge from the lifecycle. The first relates to the transition between the different stages, and the second concerns the way LOs are used in the generation of a learning programme for a specific learner.

The transitions may be managed consistently by providing relevant metadata for the learning objects. The integration of the LOs, on the other hand, may require a more structured intervention through a combination of metadata and learner profile. The deployment of schemes for personalisation and adaptivity has become an imperative for an effective application of LOs in instructional design [5]. More specifically, the adequate sequencing of LOs is seen as an integral part of the personalisation process.

The aim of this paper is to introduce a framework, which illustrates the main processes associated with the lifecycle of learning objects, and to present and demonstrate one approach to the integration of learning objects into personalised learning programmes. This presentation is also intended to shed light on topics such as the LO lifecycle, learning path construction and personalised sequencing of LOs.

The remainder of the paper is organised as follows. Section 2 deals with personalisation issues. Section 3 describes the architecture of the framework. Section 4 and Section 5 detail the learning path construction and the scheduling respectively. Section 6 gives an outline of LO rating. Section 7 presents a context for evaluation and further work, and Section 8 concludes the paper.

2. Learning object sequencing

The demand for more personalised e-learning programmes is being met by the introduction of methods and mechanisms for sequencing LOs into coherent learning paths in order to enhance the learning experience of the learner. While the profiles of learners can vary in scope and in the way they are generated, there is a broad consensus on the metadata for LOs. The convergence that the learning object metadata (LOM) has generated

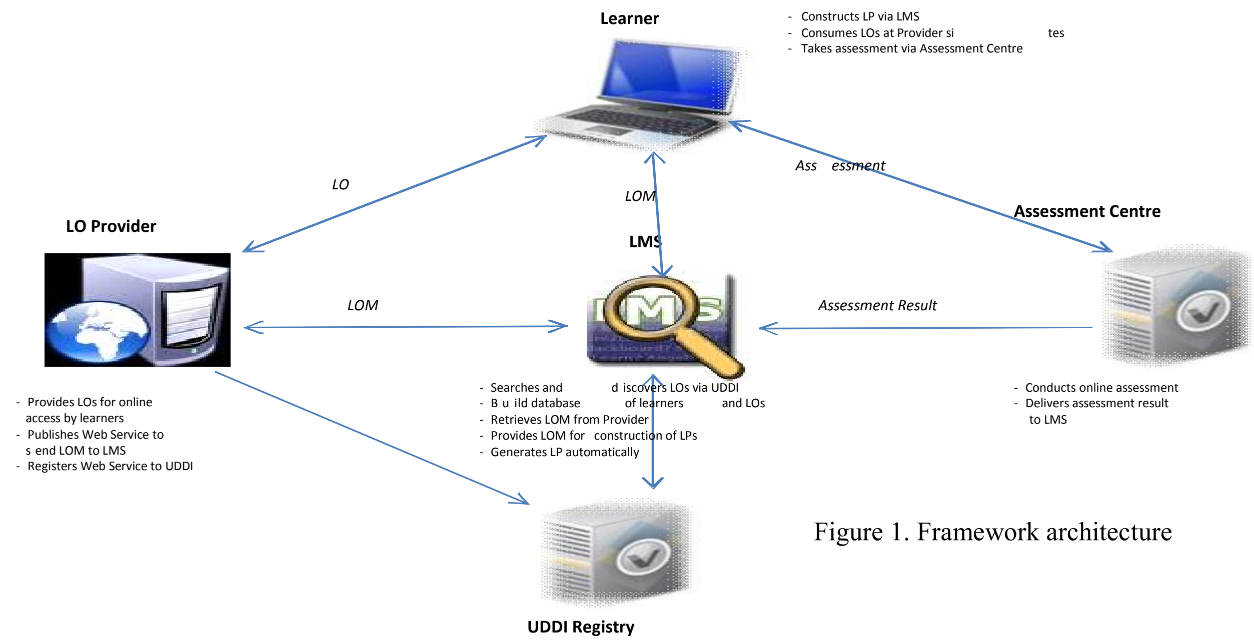

Figure 1. Framework architecture

provides some focus in design and implementation. LOM, as a conceptual metadata outline for the LOs, includes various metadata levels [6]. The classification of LOs is particularly relevant for the search and discovery especially when prerequisites are mandated. The ACM Computing Classification System is often taken as a basis for a topic specific taxonomy.

In many repositories the rating of a LO by users is becoming an important part of the metadata of a learning object and a significant component of the learning process. Highly rated LOs are more likely to be selected.

From the learner perspective, the profile may involve different facets, may be explicit or implicit and may also be generated statically or dynamically. One example of explicit implementation would be for the profile to mirror some of the categories the LOM. This approach has the advantage of facilitating the personalisation process. Personalisation may involve different cognitive requirements, such as background knowledge, learning objectives and learning style. In many of the proposed approaches, knowledge elicitation from the learner is a crucial phase. The combination of metadata and profile is an active area of research. Sun *et al* use learning style as the driving factor for personalisation [7], whereas de Marcos *et al* propose an approach based on metadata and competences to personalise courseware [8]**.** In Chen [9] it is the explicit consideration of the ability of the learner and the difficulty level of the courseware that determine curriculum sequencing.

3. e-learning framework

The design and implementation of this framework is motivated by the need to integrate three main perspectives:

1. Provision of LOs in a manageable manner through generic solutions. In the lifecycle this corresponds to the stages of development of a LO and the publication of its LOM in a registry.
2. Enhancement of the learner's ability to engage with the learning design process. The learning path is constrained by two types of dependencies: the prerequisites of a LO in terms of topics and the profile of the learner. An optimal path is generated by matching LO metadata and learner profile, and by specifying the order of activation of the objects in accordance with the learner preferences.
3. Active involvement with the learning process. The performance of the learner on a related assessment may be used to restructure the learning path dynamically, should any failure occur. Learners have also the opportunity to evaluate and rate the quality of a LO and thus enhance its metadata.

In addition to the Title, Description, Keyword, Code and URL, the metadata includes ten categories: Language, Interactivity Type, Learning Resource Type, Interactivity Level, Intended End User Role, Context, Typical Age Range, Difficulty, Typical Learning Time and Format. The classification of topics is based on the ACM Computer Science Curriculum [10]. One main topic, Programming Languages', is used to illustrate the dynamics of the e-learning framework. Eight topics were taken from the list, which appears under the 'Overview' sub-category of 'Programming Languages'. A real application would initially include categories such as 'Information technology' and 'Computer Science'. When the 'Computer Science' category is selected further categories would appear such as 'Discrete Structures' or 'Programming Languages'. 'Programming Languages' would have as sub-category 'Overview', which includes the topics used in case study, namely 'Virtual Machines', 'Basic Language', 'Translation' and so on. The categories and sub-categories define a hierarchy of dependencies, as a tree structure, where the levels correspond to the stages in the learning path.

Architecture

The architectural elements of the framework and some of their functionality are presented in Figure 1 and described below:
- The Providers of learning objects (LOs) implement their LO website and allocate a unique ID number to each LO. The unique ID number is encapsulated in the LOM and used by the LMS to determine whether the LO is recent by comparing it with the IDs of stored LOMs. The LO Providers publish the data pertaining to their web service to the public UDDI registry so that their LO can be discovered and registered by the LMS. The LO Providers also implement the method that is exposed as a web service so that they can send to the LMS a LOM for a discovered LO, by invoking the corresponding web service at the LMS.
- The UDDI registry enables the LMS to search and discover new LOs. The LMS needs to discover only the LOs belonging to a particular category. If it assumed that there exists a Learning Object ("LO") category with a Computer Science ("CS") sub-category in the UDDI registry. The UDDI data structure, *tModel*, used to describe classification and category of registered data, contains both taxonomy and technical information (with pointers to WSDL).
- The LMS discovers LOs which fall under the "LO" category with the value "CS" from the UDDI registry server and retrieves all LOMs from their respective sites by invoking the web service at the provider site. The site invokes in turn the web service at the LMS and sends the LOM to the LMS. After retrieving all the LOMs on a daily basis the LMS compares them with the ones stored in its local database and registers any new LOMs. LOMs stored locally at the LMS are used by the learners for the construction of their learning paths as well as for accessing LOs from the provider sites. The LMS provides facilities for learners to construct, manually or automatically, their learning paths and to schedule the traversal of the paths based on learners preferences. The LMS also cooperates with the Assessment Centre to assess the learner's knowledge on a particular LO and to restructure the learning path accordingly.
- The Learners register with the LMS and specify their preferences for specific characteristics of LOs as well as for the scheduling criteria. The profile of a learner includes the same categories as for the LOM. They can construct the learning path for the topic they want to study online. Learners are redirected seamlessly to the LO's website when they want to activate it in the learning path. Learners may also take an assessment with the Assessment Centre when they complete the study of a particular LO. Their progress is reflected on the learning path by white and green arrows accordingly (Figure 2|). Green arrows indicate that they have studied and completed successfully a particular LO.
- ***The Assessment Centre*** is an independent body that conducts online and/or paper-based assessments on a particular topic selected at the LMS by the learner. The Assessment Centre delivers the assessment results to the LMS by invoking the web service at the LMS.

Implementation

Appropriate technologies were used to address functional and non-functional system requirements. The system was implemented mainly in Java and Java-related technologies. The functionality of the LMS relies on a database, implemented on PostgreSQL, for holding information on Learners, Classification Topics, LOMs and LO providers. Given the interactive requirement of the system and its configurability, JavaServer Faces technology was chosen for building the server-side user interfaces. The technology provides intuitive support for the instant updates to the learning path in particular. The independence and universality of the LO providers and UDDI was also catered for by mediating all the interactions by Web Services. The JAX-WS stack is used to expose methods as web services to sends LOMs to the LMS. The jUDDI open source java implementation and the web services were deployed within Apache Tomcat.

4. Learning path construction

Learners can construct a learning path for the topic they wish to study by selecting manually the LOs or by taking advantage of the system's ability to construct the learning path automatically, based upon a learner's profile. It is expected that each LO to include the prerequisite topics, should it have any. The IDs of the prerequisites are transmitted with the LOM when the web service at the Provider site sends data to the LMS. If a LO has any prerequisite topic a learner must choose a LO belonging to that topic; the process of selection continues until all the prerequisite of the topics have been satisfied at each level. With each LO prerequisite selection the learning path is constructed gradually on the fly. In the automatic construction of a learning path, the system selects LOs by taking into account the learner's profile. A match between LO and learner can be easily calculated since they both incorporate the same criteria for classification. The most important include the desired interactivity type, the difficulty level, the learning time and the type of learning resource.

The learning path is shown as a dependency tree structure of LOs (Figure 2). The final LO is identified as the root of the tree, at the highest level. Duplicated LOs are indicated by a common colour for identification and

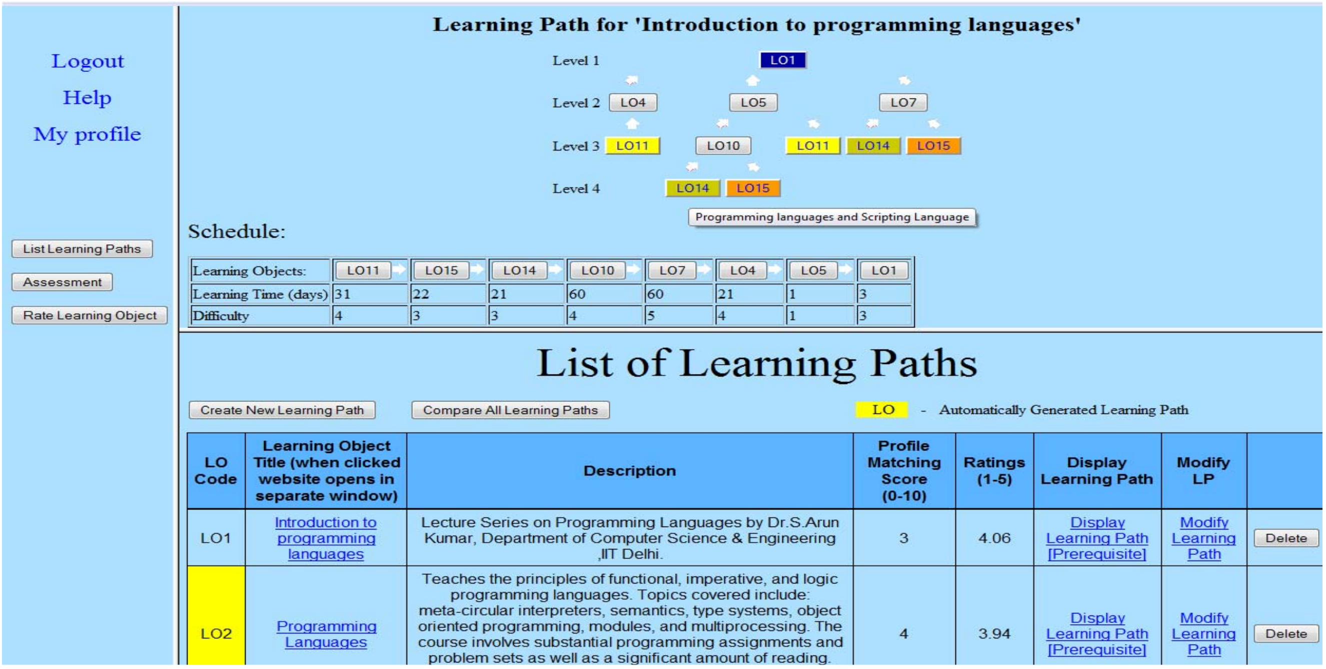

Figure 2. Learning path and schedule

scheduling purposes. The learners have also the opportunity to modify their learning paths.

The algorithms for constructing a learning path manually and automatically are basically similar. The only difference is that in the case of manual construction a learner selects prerequisite LOs by taking into account the ratings and the profile matching score, whereas for automatic construction the LMS system selects the prerequisite LOs by calculating the profile matching scores for all the prerequisites of LOs for the chosen topic. It then selects the LO with the highest profile matching score.

5. Learning path scheduling

The LMS provides a facility for scheduling the learning path to help the learners organise their learning process (Figure 2). The schedule specifies the order of the deployment of the LOs. Four criteria are taken into account when the system determines a schedule: 1) level of LO in the tree, 2) time required to learn the LO, 3) difficulty level of the LO and 4) number of occurrences of LOs in the learning path. When learners first register with the system, they are required to define their preferences in line with the above criteria. The choice for the first three criteria is as follows: 1) highest level in the tree (deepest level in the tree) or lowest level in the tree, 2) longest learning time or shortest learning time and 3) most difficult or least difficult.

In determining the schedule, the system tries to order the LOs based upon the first preference. When the first preference is not sufficient for discriminating between LOs, the second preference is invoked. Similarly, when the second preference fails to distinguish between the LOs, the third preference is taken into account. In case the third preference is inadequate, the system tries to order the LOs by the number of their occurrences by giving priority to the highest number in the learning path. If this procedure fails, the system assigns the LOs in the order it traverses the tree, which is post-order traversal. The scheduling of the learning path is done bottom up, from leaves to root, so that all prerequisites are covered first.

6. Learning object rating

The rating of a learning object consists of the sum of two equally weighted parts, the Expert Rating and the Learners Rating. A high rating corresponds to a high value. The Expert Rating is conducted before the registration of the learning object with the LMS on a scale of 1 to 5. The rating can be repeated at the request of the learning object provider. The Learners Rating is the average value of three adjacent ratings, with the highest number of voters. This method has been adopted to take into account consistent ratings and to ignore malicious or incidental ratings. On a scale of 1 to 5, the number of voters for each rating is updated when the learners vote.

There are two cases where the learners rating of a particular LO is not taken into consideration: 1) if the total number of voters has not reached some fixed threshold and 2) if there are no three adjacent ratings having the highest number of voters; the learners' rating is considered to be unreliable in this case.

7. Discussion

The framework promotes an integrated approach to e-learning by identifying explicitly the processes that punctuate the lifecycle of a LO. It also addresses the transitions between the main stages and brings together search and discovery, selection and integration, and use and evaluation of LOs. The interdependence between topics rather than LOs offers more flexibility and allows for the selection of LOs from different providers. The focus is essentially on learner-content interaction.

The LMS is a focal point of activity, which is driven by the need to generate personalised learning paths. Besides the inherent topic dependency, the construction is guided by the profile in the selection of the LOs, the preferences in the scheduling of the learning path, and the performance in the adaptation of the learning path. In its enhanced role the LMS fosters greater autonomy in instructional design by learners, and is responsive to learner performance and knowledge dependency. It insulates the learner from the complexity of instructional design by automating the learning path construction and by accommodating multiple learning paths. By enforcing a clear separation between a LO and its LOM, it decouples instructional design from courseware delivery. Furthermore, through direct access by learners to courseware at remote sites, the learning content is kept up to date. The system is designed to support easy navigation and interaction. Many features can be configured to suit the prevailing educational context.

Although the framework addresses explicitly many e-learning issues, the proposed solutions are generic and warrant further investigation on various aspects such as:

- Conformance to standards can enhance the relevance of e-learning schemes. Sole reliance on LOM however may be problematic, as research has highlighted its limitations in classification [11]. A more directed use of the metadata levels could alleviate to some extent its shortcomings. A richer set of semantics provided by ontologies will also broaden and refine the impact of personalisation [12].
- The profile of a learner is closely linked to the LOM. Although it captures various facets it can be refined by building it dynamically and by capturing elements of behaviour implicitly [13]. The profile can also include other cognitive features such as learning style and thus help ensure a better fit between learners and LOs [8].
- The implementation of UDDI registry is an example of a generic solution that can be used to integrate existing repositories within the proposed framework. Classification issues must be addressed explicitly.
- The rating used in this framework is one-dimensional and may not reflect all the characteristics of a LO. A more comprehensive approach would incorporate an evaluation instruments such as LORI [14].

8. Conclusion

In this paper a framework was proposed as a means of addressing issues related to the most significant stages of the lifecycle of a LO. In dealing explicitly with e-learning processes the focus of the framework has been on the construction of learning paths as core functionality. The main outcome of this work is that an integrated approach can help unify different perspectives and generate an optimal personalised sequencing of learning objects.

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