Reuse-based Layering: a Strategy for Architectural Frameworks for Learning Technologies

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Abstract

Efforts to develop standards for learning technologies have developed along two distinct strands: standards for data and information models; and standards for components, interfaces and architectures. Standards relating to architectural frameworks are less well developed, and responsibility for decisions concerning system architecture has been left largely in the hands of developers of proprietary software such as Learning Management Systems. There is growing interest in the development of standards for open architectural frameworks, based on layering, a decomposition technique which is in widespread use in software development. As interoperability and reusability are key concerns for developers of e-learning systems, the choice of an appropriate layering strategy is crucial, and this paper illustrates how a reuse-based layering strategy (as opposed to a more typical responsibility-based strategy) might be applied to e-learning systems in order to enhance reuse and interoperability.

1. Introduction

The development of e-learning standards and specifications is a major concern of researchers and developers of learning technologies. As standards relating to data models are relatively mature, the focus has now shifted to the development of standards for open system architectures. Drivers for the elaboration of standards for data and information models included the objectives of interoperability and reusability, and these key attributes should also drive the development of standards for architectures. Starting with definitions of interoperability and reuse from the perspectives of the software industry and the e-learning community, this paper then considers e-learning standardisation initiatives, before focusing on the issue of open architectural frameworks, summarising proposals for what has been recognised as an emerging paradigm based on layering [1]. The choice of architecture is a critical determinant of reuse potential [2], and lessons from the software industry show the importance of a layering strategy [3]. Two approaches, responsibility-based layering and the less-common reuse-based layering, are applied to e-learning systems in order to show that, since reusability and interoperability are key objectives of learning systems, a reuse-based layering strategy should be a key consideration in the future development of standards for open architectural frameworks.

2. Interoperability and reusability

Interoperability and reusability are key concerns for the learning technology community [4]. They are also preoccupations of the software development community, particularly in relation to Web services [5]. For software developers, interoperability may be defined as 'the ability of two or more systems or components to exchange information and to use the information that has been exchanged' [6]. Reusability is 'the degree to which a software module or other work product can be used in more than one computing

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program or software system' [6]. For those working on learning objects (LOs), interoperability relates to the independence of the learning object from the medium of delivery [4], but an agreed definition of reuse and the extent of reusability is not obvious, although the term is a constant in most research relating to LOs. The concept of reusability means different things to different members of the LO community, while it has a stricter definition in relation to software development.

Reuse is a key element of many LO definitions, but the importance accorded to reuse varies across projects and studies. IEEE 1484.12.1-2002 defines a learning object as 'any entity, digital or non-digital, that may be used for learning, education or training' [7]. The Learning Object Metadata (LOM) working group expanded this definition to a degree: '... any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning. ' [8]. Wiley [9] also adopted a broad definition of learning objects as 'any digital resource that can be reused to support learning' [9]: the key features are digitization and reusability. The MASIE Center published an industry report based on the outcomes of their S3 Working Group, where an LO is described as 'a re-usable, media-independent chunk of information used as a modular building block for e-Learning content' [10]. Cisco Systems [11] placed the concept of reusability at the heart of its reusable learning objects strategy, referring to the idea of 'reusable granular objects that can be written independently of a delivery medium and accessed dynamically through a database' [11].

Reusability as a theme recurred in Jacobsen's definition of reusable learning objects as 'a discrete reusable collection of content used to present and support a single learning objective' [12]. Douglas wrote of a manufacturing process, acknowledging the craft-based approach to development of components, and identifying the main advantages of components: they allow for reuse: 'a component used on one product can be used to provide the same function for another product' [13]. Reuse speeds development and allows for incremental improvement.

Until a single definition of reuse (and a single definition of a learning object) is agreed, it will be difficult to measure the extent of reuse, as well as general reactions to learning-object based technologies, since the basic concept means different things to users, learners, developers and e-learning professionals. However, such issues have already been tackled by the software development industry. Indeed, it has long been considered by proponents of object technology that it is an architectural framework that is the key to achieving reuse [14].

3. E-Learning standardisation initiatives

Efforts to develop standards for learning technologies have developed along two distinct strands: standards for data and information models; and standards for components, interfaces and architectures. Most progress has been made in relation to the specification of data and information models, thanks to the work of the IEEE's Learning Technology Standardisation Committee's Learning Object Metadata Working Group, and the IMS' Global Learning Consortium Inc., among others. Work on standardization and specifications at this level relates to metadata (including the Learning Object Metadata (LOM)); and content packaging (with initiatives such as the ADL Sharable Content Object Reference Model (SCORM)), and the IMS Content Packaging Specification; as well as learner profiles and records (through the IEEE LTSC Public and Private Information specification (PAPI); and educational content organization (with the AICC guidelines of interoperability of Computer-Managed Instruction (CMI)). A complete survey can be found at [15].

The second strand relating to standards for components, interfaces and architectures is less well developed. At this level, the specification of standard interfaces for learning objects would facilitate the construction of e-learning systems, as well as offering the promise of interoperability. Anido-Rifon et al., [15] identified three major categories of systems which have been developed: Educational Delivery Systems, such as Placeware Auditorium; Computer-Managed Instruction Systems including WebCT; and Learning Management Systems, such as Docent Enterprise.

So to date, standardization efforts have related to data and information models, in order to facilitate the interchange of data, largely through the specification of metadata for the indexing, searching and retrieval of learning objects. With such a focus on describing data, the second strand concerned with issues such as interfaces and architecture has been left largely in the hands of Learning Management Systems developers, who produce for the most part, proprietary systems. There is a pressing need to consider an open framework for interfaces and architectures so that different parts of an e-learning system can communicate with each other.

4. Open architectural frameworks

For the purposes of this paper, architecture is the blueprint used to design a learning system, or 'the structural relationship between the individual components that together create an application as a whole' [3]. Wilson [1] reported on three distinct approaches to an open learning systems' architecture, and spoke of an 'impending paradigm shift away from only providing compatible data files to designing a framework that would allow fully interoperable systems to be developed'. All proposals shared a layered approach to an open architecture, although each had a different focus.

The first proposal was a service-based model, focused on components, where components provide common services, and the client interfaces with the services it needs through a broker which manages requests. The layering of this model proposed by Mark Norton of IMS was layering of integration, where components are loosely coupled. The first layer is database integration (based on XML, for example); the second is message-based (using protocols such as SOAP); and the third layer is software integration (achieved through APIs, for example).

Dan Rehak proposed a second model, also based on layering of a service stack. At the top are user agents, with tools at the next layer for collaboration, assessment and simulation, followed by application services for content management or sequencing, and finally, infrastructure for services which are common across applications [16].

A third approach developed by Scott Thorne as part of the Open Knowledge Initiative (OKI) focused on interfaces at the programming level, as it is based on Application Programming Interfaces (APIs). This layered architecture has user interface objects, then OKI services, followed by common services. All these proposals share a layering strategy for a service-based model, combined with a components-based approach. This addresses the key concerns of interoperability (as it service-based) and reusability (as it is component-based). By 2002, these separate initiatives had come together in a loose alliance [17].

5. Responsibility-based layering applied to e-learning systems

Layering approaches are well developed in the software industry: the Open System Interconnection (OSI) 7-layer model is a well-established generic networking framework, where control is passed from one layer to the next [18]. A similar layering model is the 3-tier model, with the tiers or layers of presentation logic, business logic, and data access logic. This is the most common approach used in web applications; it breaks an application into logical chunks, and as component roles are well defined, this is good for reusability [19].

Both these layered systems (the 3-tier model and the OSI 7-layer framework) adopt a responsibility-based layering strategy, and they are based around dependencies: any element in a layer can only access elements in that layer or those below it. Most of the substantial work on standardization of learning systems has concentrated on the third tier of this model, the data access tier.

There are different layering strategies which can be adopted; these include layering based on responsibility, reuse, security, skill sets and ownership [2]. The most common strategy is responsibility-based layering, which is the approach adopted by many e-learning systems. The advantages of this strategy include improved system development and maintenance.

The layers and content for a typical section of an e-learning system can be represented as follows (Figure 1 below): a typical e-learning system might have the concepts of Learner, Course and Module. The Learner concept might include classes such as the LearnerView class, which deals with the presentation logic for a learner, the Learner class, which deals with the business logic through, for example, validating learner details, and the LearnerData class which handles the data access logic for a learner, such as title, name, date of birth, and so on.

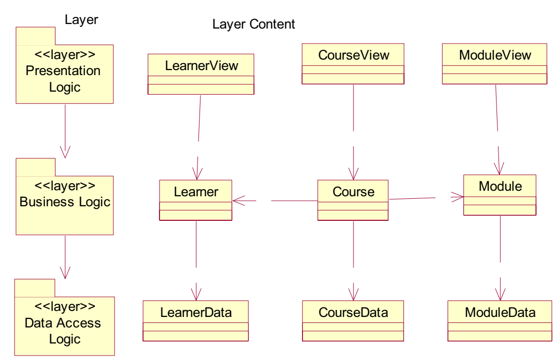

Figure 1. Responsibility-based layering, adapted from [2]

This strategy relates to both design and implementation models of a learning system: for example, the elements in the presentation layer reside in an application that is deployed on the client, while the elements in the business and data access layers could reside in an application on a server.

6. Reuse-based layering applied to learning systems

There is, however, another layering strategy: reuse-based layering, which is considered to be of particular use where an organization has the clear goal of reusing components [2]. Such a goal would appear to be at the heart of most e-learning systems, so this type of layering might better serve the objective of reusability. With reuse-based layering, components are grouped according to the level of reuse; thus, the potential for reusability is moved to the foreground. Figure 2 below illustrates how such a strategy might be implemented for an e-learning system.

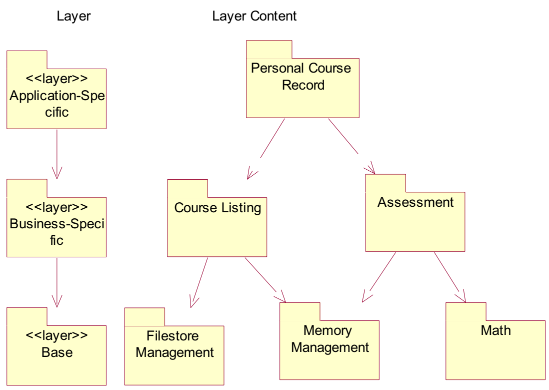

Figure 2. Reuse-based layering, adapted from [2]

The focus and content of the layers is different from responsibility-based layering. With a reuse strategy, there are three layers: base, business, and application. The base layer is composed of elements or assets which can be used across organizations. These might be elements such as Math functions, for example. The business layer is composed of elements which are independent of an application, but apply to a particular organization, such as CourseListing. This element could be reused in the organization. The application layer comprises elements which are related to a particular project or application, such as in this case a PersonalCourseRecord, or a GradeBook. The elements in this layer have the least potential for reuse. It is those elements at the base layer which have the potential to be most widely reused, as they apply across organizations. In a reuse-based system, the dependencies tend to occur between elements in the business layer.

7. Conclusions

The choice of an appropriate layering strategy is considered to be one of the most important decisions to influence system architecture [2], and an appropriate architectural framework will promote reuse [14]. A layered architecture will in turn enhance interoperability. A layering strategy will influence system development and maintenance, and a reuse-based strategy will explicitly enhance reuse, as reusable system elements can be readily identified. Since reusability and interoperability are key objectives of learning systems, a reuse-based layering strategy should be a key consideration in the future development of standards for open architectural frameworks.

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