CREATING SHARABLE LEARNING OBJECTS FROM EXISTING DIGITAL COURSE CONTENT

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ABSTRACT

Our research is targeting Instructors that have course material as a collection of various digital documents (raw content) and whose objective is to re-structure this raw content into a standards-based format in order to support a higher degree of content reuse, sharing and easier maintenance.

In previous work, we differentiated a Reusable Learning Object (RLO) from a Sharable Learning Object (SLO) and developed a model which can be applied to convert RLOs into SLOs [4]. In this paper, we present an iterative five-step method to re-structure selected raw content into RLOs. The model from the previous work is then applied to convert the RLOs into SLOs.

Thus far, we have used raw content from one Instructor's Computer Architecture course and found that conversion of the raw content can successfully result in a subset of the raw content residing in SLOs, a form which is more conducive to reuse, sharing and content maintenance.

In ongoing work, we are applying the methodology to additional raw content from several other Instructors (Computer Science courses) with a view to refining and automating the process where possible.

1. INTRODUCTION

Many instructors have developed or have access to digital content for their respective courses. It is usually the case that most of the content (which we will call *raw content*) is a collection of documents in various formats such as PDF, HTML, XML, other documents created with Word Processor applications, and an abundance of slide-documents created with presentation applications, and in recent years, multimedia (audio/video) documents.

While Instructors have, in the past, successfully used such content in the physical classroom environment, they are now challenged to adapt their material to support eLearning goals. The term eLearning is defined to be *learning in an environment where the classroom is no longer a physical entity in the learning process, but transcends space and time with the use of computers and computer-related technologies* [1]. The classroom is thus a digital classroom. Having a digital classroom means, that the content (digital content) placed in standards-based eLearning systems receives more opportunities for reuse and sharing. It is therefore desirable that the content be structured to allow both maintaining the relevance of the content over time, as well as pedagogically defined to be contained in a vessel to promote reuse and sharing among different courses.

Some Instructors are discovering that transporting existing raw content into eLearning systems using Content Packaging standards does not necessarily produce reusable and sharable content, because there is no pedagogical framework involved. For example, the SCORM Content Aggregation Model (CAM) [2] facilitates the storing, aggregating, sequencing and packaging of raw content into course modules and courses, but the content itself can exist in forms (raw content) that are difficult to maintain, reuse and share.

Gehringer [3] reported that it was difficult to achieve sharing of Computer Architecture course documents (raw content) among Instructors. One reason given by the Instructors was that they had obsolete and unpolished content within their collection of raw content.

With issues such as these in mind, our aim was to develop a method that will select existing raw content and re-structure it to facilitate reuse and sharing among standards-based eLearning systems. The standards-based format is a Sharable Learning Object (SLO), which we can concisely define as *a content vessel with pedagogical constraints*.

The full definition of a SLO is given and explained in Section 2. Section 2 also describes the method for re-structuring selected raw content into SLOs. In addition, some comments are included as part of the methodology since we have applied it to select raw content from one instructor's Computer Architecture course (CS21E).

We review in Section 3 the infrastructure required for using SLOs, and identify how far we have reached with the design and implementation of the infrastructure.

Section 4 gives the conclusion, some ongoing and future work, followed by the list of references.

2.0 CREATING SHARABLE LEARNING OBJECTS

The method that we have developed takes selected raw content and re-structures it into Sharable Learning Objects (SLOs). The method would not necessarily produce a complete set of SLOs that can be aggregated and sequenced to reproduce what the raw content may have successfully been able to achieve. This is due to the pedagogical nature of our SLO, where content must be appropriately matched to a Single Learning Objective for inclusion. Selected content is placed in what we call a Reusable Learning Object (RLO). The distinction made between a RLO and SLO is given next.

2.1 Distinction between a Reusable Learning Object and a Sharable Learning Object

In previous work, Singh and Bernard [4] defined and differentiated a Reusable Learning Object (RLO) from a Sharable Learning Object (SLO). The definition which follows was originally adapted from Cuthbert and Himes [5], and Figure 2.1 is a conceptual representation of the SLO as implemented:

*A **RLO** is a reusable chunk of content with the following **two fundamental properties**:*

- *instructionally sound content with a focused learning objective*
- *facility that allows the learner to practice, learn and receive assessment*

*and, a **SLO is a RLO** with the following additional **Interoperability property**:*

- *metadata or keywords that describe the object's attributes and mechanisms for communicating with any eLearning System.*

Note that the latter part of the Interoperability property is what determines if a RLO is sharable. We used the Sharable Content Object Reference Model (SCORM) Runtime Environment (RTE) [2] to implement this part of the property. The first part of the Interoperability property ensures that a specific SLO can be discovered among others in a repository of SLOs. In implementing this first part, we applied metadata to the SLO as specified by the SCORM Content Aggregation Model (CAM) [2].

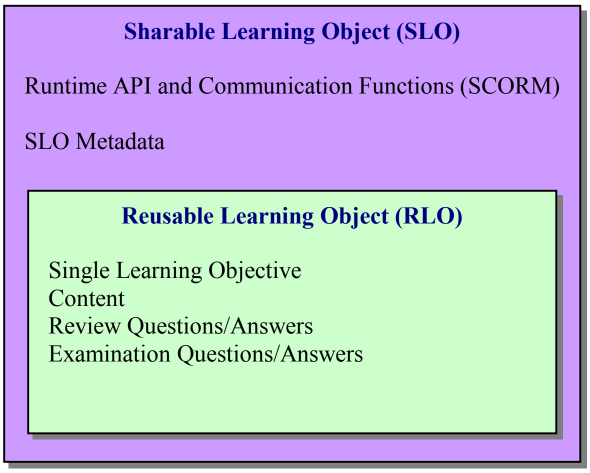

Figure 2.1 – Conceptual representation of a SLO

2.2 Methodology used to extract existing digital content into Reusable Learning Objects

The aim of this methodology is to select and extract as much of the existing raw content into Reusable Learning Objects.

The approach is an iterative five-step process to select appropriate content for the RLO with opportunities to refine and re-structure as the extraction is taking place. The steps are as follows, along with some experiences we had with the Computer Architecture course (CS21E):

1. ***Start with a high-level syllabus, and create a detailed Table of Contents (TOC) for the course where each learning topic and subtopic can be easily identified.***

   In most cases, a document should already exist with this information. The CS21E course had such a document, and we simply refined it to produce the TOC as required. It is quite reasonable to expect that the refinement continue while the other steps are taking place. Figure 2.2 is a partial listing of the TOC we used for the CS21E course.

2. ***Review each topic/subtopic and list as many Learning Objectives as possible as non-conjunctive sentences so that each sentence deals with one and only one Learning Objective.***

   Learning Objectives are statements of what the learner will be able to do after studying the content [6]. An example of a Learning Objective statement is "*The learner would be able to decompose the Instruction Cycle into subtasks*". Content must only relate to the single Learning Objective, hence the reason why we require non-conjunctive statements.

Figure 2.3 lists a set of Learning Objectives for some of the topics/subtopics shown in Figure 2.2.

Pipelining:
- Introduction
- Instruction Cycle
- Throughput
- **Hazards:**
  - Introduction
  - Structural Hazard and Solution
  - **Control Hazard and Solutions:**
    - Introduction
    - Multiple Streams
    - Pre-fetch Branch Target
    - Loop Buffer
    - Branch Prediction
    - Delayed Branch
  - Data Hazard and Solution
- **Review Questions:**

Micro-Operations:
- Introduction
- Fetch Cycle
- Interrupt Cycle
- Execute Cycle
- Micro-Operations Flowchart
- **Review Questions:**

Input/Output:
- Introduction
- I/O Module Function
- I/O Module Structure
- **I/O Techniques:**
  - Programmed I/O
  - Interrupt Driven I/O
  - Direct Memory Access
- **Review Questions:**

Figure 2.2 – Partial detailed Table of Contents for the CS21E course

3. *Select the associated raw content for achieving each Learning Objective identified.*

In this step, select, separate, edit and refine the appropriate content for each Learning Objective. This process will involve the copying and pasting of content from the original documents to form new documents (called Assets) with only the selected content. It is important to ensure that navigational links are maintained when multiple Assets are created so that the flow of content is as intended. A main Asset should be identified, which is the one with the starting content. At this point, we can set up a RLO document to have the Learning Objective, and reference the main Asset. The navigational links will include the related Assets. Figure 2.4 (a) and 2.4 (b) depicts a scenario with multiple Assets.

Pipelining:
- Introduction
  - ✓ *Be able to decompose the Instruction Cycle into subtasks*

    <Content …Instruction Cycle… />
  - ✓ *Be able to identify how pipelining improves throughput*

    <Content …Throughput… />
- **Hazards:**
  - ✓ *Be able to identify when a hazard can occur*

    <Content …Introduction… />
  - ✓ *Be able to solve the problem of a structural hazard*

    <Content …Structural Hazard… />
  - **Control Hazard and Solutions:**
    - Introduction
    - ✓ *Be able to solve the problem of a Control Hazard using Multiple Streams*

      <Content …Multiple Streams… />
    - ✓ *Be able to solve the problem of a Control Hazard using Pre-fetch Branch Target*

      <Content …Pre-fetch Branch Target… />
    - ✓ *Be able to solve the problem of a Control Hazard using Loop Buffer*

      <Content …Loop Buffer… />
    - ✓ *Be able to solve the problem of a Control Hazard using Branch Prediction*

      <Content …Branch Prediction… />
    - ✓ *Be able to solve the problem of a Control Hazard using Delayed Branch*

      <Content …Delayed Branch… />
  - ✓ *Be able to solve the problem of a Data Hazard*

    <Content …Data Hazard… />
- **Review Questions:**

FIGURE 2.3 – Learning Objectives for some of the Topics/Sub-topics shown in Figure 2.2

4. *Include the Review Questions/Answers.*

In other definitions of Learning Objects [7] this part is not necessarily integrated, however we believe that it should be part of the RLO since the Questions/Answers we are identifying for inclusion should be directly related to the Learning Objective and content. In this way, both the learning content and the formative assessment activities contribute to achieving the learning objective and are stored together as an integrated whole.

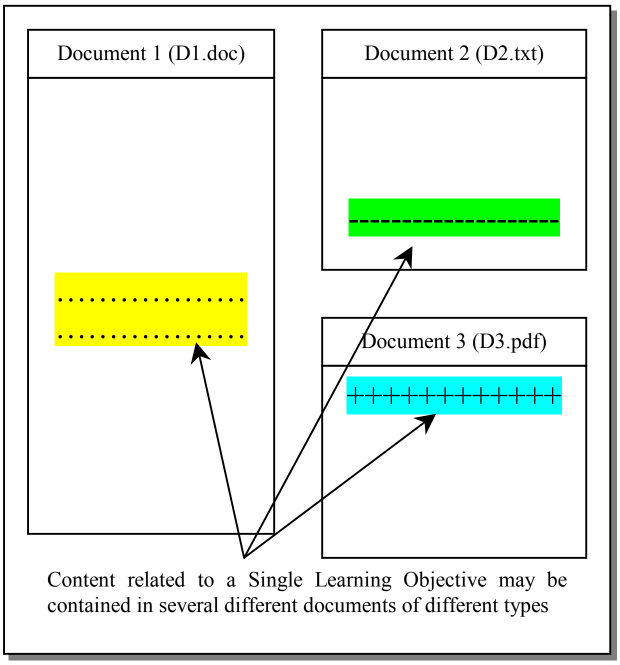

Figure 2.4 (a) – Multiple documents with content

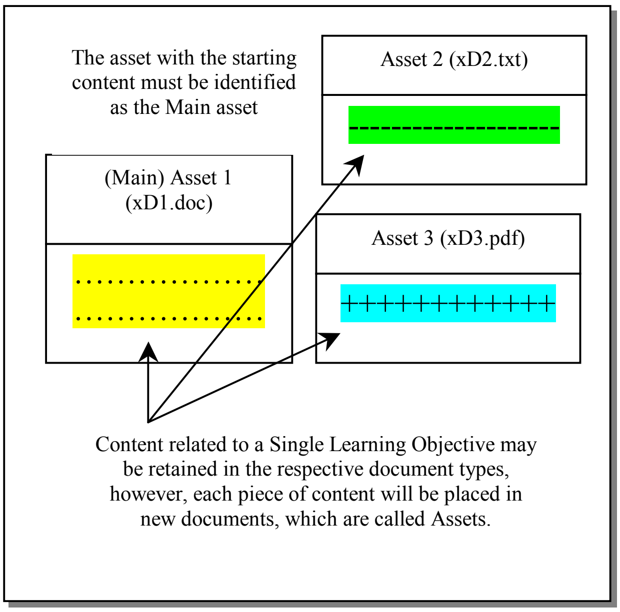

Figure 2.4 (b) – Multiple assets for a single RLO

5. ***Include the Examination Questions /Answers.***

The Examination Questions/Answers is a preferred set of Questions/Answers that can be used by instructors for examinations purposes for summative assessment. Review Questions /Answers can be referenced here as well. Again, the Questions/Answers should be directly related to the Learning Objective and related content.

2.3 Transforming Reusable Learning Objects into Sharable Learning Objects

In order to transform a RLO into a SLO we must add metadata and include communication functions. The metadata will describe its properties which can be used to determine, to some extent, how an eLearning system (Learning Management System – LMS) should interact with it. The metadata is also used to facilitate discovery of the SLO when it is placed in a Digital Repository (see Section 3). Communication functions will allow a LMS to know what interactions are taking place between the Learner and the SLO so that the LMS can interact intelligently in the delivery of the course material.

The SCORM metadata standard for Content Objects [2] was applied to the SLOs. This metadata standard is based on the IMS [8] and LOM LTSC [9] metadata standard. We chose this standard because the metadata for each SLO can reside as a standalone XML document, thus lending support to the SLO structure depicted previously in Figure 2.1. The specifications are given in the SCORM metadata XML Binding [2].

To create different metadata documents for each SLO we used a template-metadata document with all the generic data filled-in, then replicated the document for each SLO and filled-in the unique data.

A model developed in previous work [4] allows the functions to be automatically attached to a RLO when converting to a SLO. For the communication functions we chose the SCORM RTE [2], and implemented the minimal set which includes a function to locate the LMS Application Programming Interface (API) when the SLO is first launched, then a call to LMSInitialize() to initialize the SLO and inform the LMS that it has been launched successfully or unsuccessfully. When the Learner completes reviewing the content presented by the SLO, a LMSFinish() function is triggered to let the LMS know, so that the next SLO sequenced can be launched or the course ended.

Adding the metadata and including the functions identified above satisfies the Interoperability property for transforming the RLO into a SLO.

3. INFRASTRUCTURE REQUIRED FOR USING SHARABLE LEARNING OBJECTS

This section gives a brief insight into the standards-based environment where SLOs can reside, and how to use existing standards to aggregate, sequence and package SLOs into modules and courses. It also identifies our current research and implementation status with respect to each aspect of providing an overall infrastructure for standards-based eLearning.

Digital Repository

SLOs are usually placed in a Digital Repository (DR) where facilities exist for their discovery. That is, search and selection based on the metadata, which describes the SLOs properties. In addition, by including a single Learning Objective for each RLO we will be able to perform searches in the DR based on Learning Objectives, which will allow for a focused discovery of more relevant SLOs.

Currently the SLOs that we have created for CS21E are held in directories, which are manually maintained. The design of a Digital Repository (DR) is still under consideration, however, our choice may be to use the IMS Digital Repository Interoperability (DRI) standards [10] to maintain the DR, since the goal is to have a standards-based DR.

Aggregating and Sequencing

In version 1.3 of the SCORM, standards were introduced to specify aggregation and sequencing of SLOs [2]. Having selected relevant SLOs, we can then aggregate and sequence into a module or course where the navigation among the SLOs is specified as part of the sequencing. We were unable to reproduce the entire CS21E course using our pedagogically defined SLOs, since we had an incomplete set of SLOs. The set is incomplete because some content is related to multiple Learning Objectives and was therefore not selected to be in a SLO. We continue to review possible solutions to this problem. In the interim, we can allow a deviation from the SLO definition for the problem cases, and allow multiple learning objectives and content. This approach would produce SLOs of a higher granularity, which has less opportunity for reuse, sharing, and are more difficult to maintain, but can be included in the aggregation and sequencing to reproduce the original module or course.

Packaging

As initially mentioned in Section 1, the SCORM CAM specifies how to package SLOs that have been aggregated and sequenced into a module or course for transporting between different SCORM conformant eLearning Systems. Such a package is called a Content Package [2]. We produced our Content Packages, inclusive of aggregating and sequencing using an application available from an opensource project [11].

Publishing

Content Packages are created for publishing or presenting to the Learner. Our publishing application is being developed as part of a larger opensource project [12], and is close to first-alpha completion (by August 2004). Notice in Figure 2.4 (b) that we have no restriction on document types for Assets. This is because our publishing application accepts multiple input formats and present the content in one user selected output format.

4. CONCLUSIONS, ONGOING AND FUTURE WORK

The paper presents an iterative five-step method to re-structure selected raw content into Reusable Learning Objects (RLOs). A previously proposed model is then applied to convert the RLOs into Sharable Learning Objects (SLOs).

We found that re-structuring of the raw content was a time-consuming event, which was due mainly to the enforced pedagogical structured definition we had for a RLO. Our approach has however resulted in a set of SLOs which we believe are of superior structural quality than the original raw content since they are more conducive to maintenance, reuse and sharing among standards-based eLearning systems.

It is important that a guided process, as we have described, exist for instructors to transform existing raw content to eLearning environments, since it will promote a more open approach for content reuse and sharing, which can in turn facilitate continuous refinement on content quality and relevance.

As ongoing work, we are continuing conversion of some other (Computer Science) courses for which Instructors have supplied raw content, and are considering ways of automating the process as much as possible in order to reduce the conversion time.

Further, the intention is to eventually design and create SLOs for most of the Computer Science courses offered by the Department of Mathematics and Computer Science at the University of the West Indies. The aim is to support initially blended-learning, fully online degree offerings, and then progressively extending both forms to other departments and faculties at the University, which will extend our online reach to Caribbean students. Currently, some courses are being offered using WebCT [13], however, the course material used are all raw content. If more courses are heading towards full online degree offerings then it is best to have the content in the form of SLOs with supporting infrastructure as described.

One additional and very important area that we are looking at is the issue of content quality. The approach that is being considered is to have the SLOs in an internationally available Digital Repository (DR) for discovery and reuse in courses that may be offered at other tertiary-level institutions, and to facilitate peer-review and rating based on quality and relevance of content within each SLO.

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