Automatic Validation of Learning Object Compositions

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***Abstract*— Course construction using reusable learning objects is becoming ever more popular due to its' efficiency. The course creator who uses this methodology may face problems due to the fact that he or she is not as intimately involved in the creation of every element of the course. In this paper we discuss one such problem faced by course creator known as "the competency gap". Here, we define the competency gap, explain how it can be identified and suggest ways of correcting the problem.**

I. Motivation

It is well understood that courseware is costly and time-consuming to create [1]. One popular way of alleviating these problems is through reuse. The Learning Object (LO) is a small unit of instruction that can be reused in many lessons, typically a slide show, tutorial or a test. Course creators no longer reinvent the wheel everytime they create a course by creating learning material that exists, but instead locate relevant learning material needed for a lesson and combine it with other LOs.

This new methodology of creating courses raises the course creators level of abstraction. They are no longer concerned with the minute details of learning material, such as the content of an individual paragraph, but are more interested in seamless integration of LOs.

As a consequence of using LOs, the course creator does not have an intimate knowledge of the contents of each course element (i.e. The LO). This can lead to competency gaps in the course. A competency gap is where there are two LOs sequenced one after another, for example, LO_1 and LO_2. LO_1 provides the learner material on a particular concept, referred here to as, $concept_a$. The assumed effect of the learner interacting with LO_1 is that he or she gains a competency in $concept_a$. When the learner has completed LO_1 he or she is directed to LO_2. LO_2 provides learning material on $concept_c$, but in order for the learner to comprehend $concept_c$ he or she must have a competency in $concept_b$. There therefore is a competency gap, as the learner does not have a competency in $concept_b$ and $concept_b$ has not been covered by the preceding LOs. Further details on competency gaps will be given later in the paper.

Since new knowledge must be rooted in a learners existing knowledge, competency gaps can be a major problem and finding them is of utmost importance. Identification and rectification of these competency gaps is a problem that must be addressed for the course creator to entrust major elements of course development to automatisation.

In this paper we look to address this problem, by reusing and repurposing technologies developed for Service-Orientated Technology (SOA). SOA technologies would not be an obvious candidate for the problems faced in the automated locating of, and rectifying of competency gaps. We hope to show where similarities exist between the creation and management of service compositions and LO compositions, and how they can be exploited.

II. Problem Definition

Course validation is ability to recognise competency gaps in a course. When course validation fails, meaningful data must be extracted about competency gaps found in that course. Competency gaps in a course should then be rated according to their effects on learning. The problems, with more detrimental effects on leaning, should be given a higher priority. After identifying competency gaps, the course creator must rectify and correct the competency gaps.

Course correction looks at how the competency gaps found during course validation can be rectified. In order to provide the course creator with a complete solution, we will also look to recommend how to correct invalid courses to the course creator.

As mentioned in the previous section, a competency gap exists when an aspect of a LO is not grounded in existing learner knowledge at the point in time when the learner has to interact with it. For example, a LO that states "Subtraction is very like addition" assumes the learner knows about addition. A valid course is one where each component of the course is grounded in existing knowledge, in that the learner has any pre-requisite knowledge necessary to fully comprehend the learning material presented in the LO to achieve the LO's learning objective.

Figure 1 demonstrates the existence of a competency gap within a course. A course can be defined as a composite LO. The composite LO in figure 1 is made up of three smaller learning objects. This composition is designed to teach a learner who knows to count about the basic mathematical operators, addition, subtraction, multiplication and division. Each LO, including the composite LO has pre-requisite and a post-requisite competencies. We can evaluate the learners presumed competencies at various points in time denoted by 't'. At t_1 the learners knowledge can be defined as knowledge=counting. At t_1 the learner wishes to engage with the first learning object, as the learner has the necessary pre-requisite we presume he will accomplish the learning goals of the first learning object with the effect of the first learning object on the learners knowledge will be the competency gained, as indicated by the LO post-requisite (in this case - addition). At this point (t_2) the learner's knowledge can be defined as knowledge=counting, addition.

At t_3 the learners presumed knowledge can be defined as knowledge=counting, addition, subtraction, the subsequent LO after t_3 has a pre-requisite of "Multiplication", as the learners presumed knowledge does not include multiplication, we can conclude that a "competency gap" exists. In order to fill the competency gap we would need a LO with a pre-requisite competency that the learner possesses (i.e. counting, addition or multiplication) and a post-requisite competency of multiplication (the pre-requisite of the target LO in the competency gap). To do this would "bridge the competency gap"

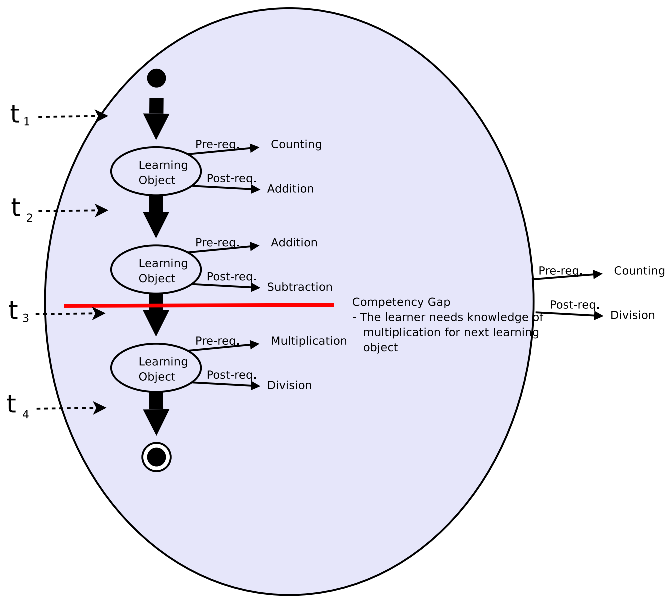

Fig. 1. WSPO4TEL

III. Research Hypothesis

Service Orientated Architecture (SOA) [2] has made a big impact on software engineering methodologies. In the future this will be further amplified due to the integration of Semantic Web technologies [3] with SOA. SOA allows for the rapid development of software by providing ready-made functionality in the form of web services that can be used by software applications. The Semantic Web allows for machine-readable detailed descriptions of these services leading to more sophisticated ways of composing software which use services.

Small parallels can be drawn between Web service composition and learning object compositions. Web services are brought together into a composition to solve some business problem, learning objects are brought together to satisfy some learning need. Similar infrastructures have been built around the technologies, LOs are described using the IEEE Learning Object Metadata (LOM) standard [4], while businesses and business services are described using ebXML allowing for a B2B electronic marketplace on the internet. Specialised repositories have also been built to store for these new technologies both for the LO and for businesses conducting ebXML business.

Semantic Web technologies are being applied to SOA to see if service compositions can be composed more easily, and to make SOA more robust. OWL-S is an ontology (a shared formal, specific conceptualisation of a domain [5]) developed using the Web Ontology Language (OWL) and used to describe the functionality of a service [6]. OWL-S describes semantically the input and output of the service, the purpose of the service and also any non-functional details such as "quality of service", allowing for easier discovery of that service. The extending of the IEEE LOM with semantic data is investigated in [7] in a bid to automatically assemble LO into meaningful compositions. This approach used a combination of ontologies, including a domain ontology and the ALOCoM ontology, which documented the pedagogical role (lesson, test) of a LO and its content structure role (paragraph, definition).

SOA has seen a desire to define service execution within a process. This has been done using the Business Process Execution Language for Web Services (BPEL4WS) [8]. There has been a similar desire to describe LOs as part of a learning process, or learning sequencing. The IMS Simple Sequencing Specification (SSS) [9] allows course creators to define a learning process using similar logical constructs to that found in BPEL4WS, such as choice and iteration.

Other ontologies used to describe services and the service execution process include the Web Service Modeling Ontology (WSMO) [10] and Web Service Process Ontology (WSPO) [11]. WSMO aims to go further than OWL-S by describing all aspects of web services such as service choreography and orchestration with other services. WSPO is used to describe services in a service composition. WSPO concentrates on the software process, where services provide some functionality in that process.

The semantic web allows the automation of web service discovery, composition and integration. If similar infrastructure is built around LOs can we use it to validate LOs manually integrated, and if LO compositions are found to be invalid can we find and recommend LOs that will validate the LO composition? The principle aim of this research is to exploit infrastructure already built in one domain for use in another.

We have summarised the similarities between SOA and LOs in table 1.

IV. Research Methodology

We have identified many parallels between SOA technology and LO technology. Service discovery and integration is a major research area in semantic web services research. We need

TABLE I

COMMONALITY IN WEB SERVICE AND LEANING OBJECT NEEDS AND THEIR TECHNOLOGICAL SOLUTION

	Web Service	Learning Object
Syntactic Metadata	ebXML	IEEE LOM
Syntactic Process Description	BPEL4WS	IMS Simple Sequencing
Semantic Metadata	OWL-S	ALOCoM
Semantic Process Description	WSPO	?
Storage	UDDI/ebXML core library	Learning Object Repository

to investigate how this research can be used and repurposed for LO composition, validation and discovery.

Our research question can be divided into two main parts. Firstly, how can LO compositions be validated, and secondly, how can we rectify invalid LO compositions?

A. *Learning Object Validation*

LO composition validation is a relatively new question where service composition validation has been investigated for quite some time. If we can exploit the process-orientated similarities between LO compositions and service compositions we can repurpose some of the infrastructure built around service composition. Repurposing the WSPO, originally designed for SOA processes, for learning processes has been explored in [12]. Figure 2 demonstrates how the WSPO (or WSPO4TEL) has been repurposed for Technology Enhanced Learning (TEL). WSPO4TEL views a LO as a learning activity within a learning process. Learning activities are defined by pre-conditions, which include needed input and learner knowledge and post-condition, which include the effect on the learner and any feedback. WSPO4TEL linked to a common domain ontology would suffice in establishing if there exists any competency gaps in a course.

B. *Learning Object Recommendation*

The second part of our research question, is that of LO recommendation. In order for a LO to be discovered according to our needs, we need LOs in LORs to be defined in terms of their pre- and post-requisites using the WSPO4TEL. Searching for LOs could be done based on the competency gap definition. The LOR aims to fill the competency gap by locating a LO that has the correct pre- and post-requisite or a composition of LOs that fill the competency gap.

The ordering of recommendations is based on the similarity between the candidate LO and the LOs nearest to the competency gap. The similarity is based on the LO's attributes as set out using the IEEE LOM. For example if the LOs before and after the competency gap are 20 minutes and 18 minutes long respectively, it makes sense for LOs with a similar time to be ordered higher than those LOs which are an hour in duration.

In order for us to adequately assess the similarities between LOs, many of the values of the IEEE LOM will have to be reference controlled vocabularies, such as an ontology.

C. *Evaluation*

To evaluate the success of our course validation and subsequent LO recommendation, we will hand build a few courses with varying complexity. These courses will consist of learning processes that are valid both in terms of pedagogical flow and contextually. We will also have a LOR, storing LOs using the WSPO4TEL. Validation will consist of randomly extracting LOs from the course and insuring validation results are correct, and that the LO recommendation is correct.

V. RELATED WORK

The use of semantic web technologies in the automatic assembly of LOs has been investigated in [13]. In this work Farrell et. al. look at how the needs of the knowledge worker can be met by automatically locating relevant LOs and sequencing those LOs in the most pedagogically sound manner. In this work, there are two levels of sequencing a path generation service for developing a coherent path through the concepts to be covered, otherwise known as inter-conceptual sequencing. When the concepts have been sequenced, a sequencing service sequences intra-conceptual elements. These are learning materials to do with the same concept, such as an example and an introduction.

Another paper which looks at strategies to sequence learning content is [14]. In [14], Ullrich looks in particular at sequencing at the inter-conceptual level. Ullrich investigates how Hierarchical Task Network (HTN) planning can be used to sequence learning material about the same concept. HTN has been reasonably successful in representing and applying sequencing strategies to learning content. HTN is very expressive and allows the course creator to set very particular sequencing strategies. Unfortunately it is not very intuitive and has an excessive learning curve associated with its usage. It also does not consider inter-conceptual relationships which are the main focus of our problem.

Course validation has been trialled in a commercial setting by Carnigie Technology Education as set out in [15]. The tool known as the Concept-based Courseware Analysis (CoCoA) was used course consistency and quality. CoCoA uses two types of relationships for validation; typed items and advanced concept roles. Typed items allow for validation of the positioning of particular teaching operations. Advanced Concept Roles validates the concept particular learning material teaches, and ensures that the learner has the necessary knowledge to fully comprehend the concept. This is done by

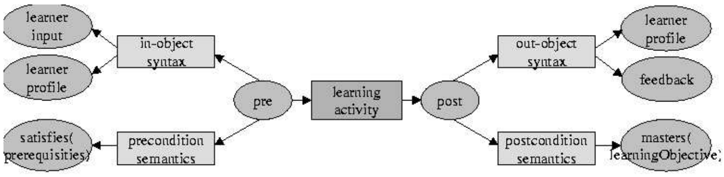

Fig. 2. WSPO4TEL

checking the concepts pre-requisites. A concept has two types of pre-requisites, strong and weak pre-requisites. Strong pre-requisites indicate the learner must have deep knowledge of the pre-requisite concept in order to understand the concept to be taught while weak pre-requisite means surface knowledge of the pre-requisite concept will suffice.

CoCoA checks each potential learning path through the learning material by simulating a learner's progression through the learning material. The tool then generates a report once all simulations are complete, this report will indicate any "content holes", where the learner is taught a concept without the necessary pre-requisite knowledge.

CoCoA represents the importance being placed on course validation. We hope to build on this work by reusing and repurposing SOA technologies.

VI. Conclusion

Should the reuse of LOs take off in a big way, the level of abstraction for the course creator will be risen in a way that is unprecedented. Many course creators may be alarmed at the thought of losing control of course content, and not being as close to the course content, due in part to the problems discussed in this paper. This project aims at alleviating some of those fears by giving the course creator the facility to check for competency gaps and to insure that all LOs fit the lesson in which they are placed.

Discovery of LOs within LORs is a major problem. We argue that defining LOs using a set of pre-requisites and post-requisites to be a more accurate way of defining the LO needed by for a lesson.

We are aware of many other problems outside the scope of pre- and post-requisite validation, such as LO context. For example take a learner who is doing a course, "Introduction to Computer Programming". The majority of the course is taught through Java, but one LO that the course creator has used uses examples from C++. This is unacceptable for the learner, and causes the learner to become unmotivated. We also wish to incorporate this contextual validation in our work.

Our hope that this will lead to better quality online courses, and less "lego courses" online, and courses constructed of LOs with the same flow as that of traditional courses.

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