Just-in-time Generation of Pedagogically Sound, Context Sensitive Personalized Learning Experiences

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Abstract

The just-in-time generation of personalized learning experiences requires the assembly of atomic learning assets into coherent learning activities for a learner, based on their preferences and requirements. Through the appropriate application of strategy to a learner's learning activities the effectiveness and efficiency of their learning can increase significantly. The strategies behind this process should be pedagogically informed to ensure the learning experience is suitable for the learner and the environment in which they are carrying out their learning. By utilizing appropriate pedagogical strategies in the personalization process, learning objects generated for a learner will not only be appropriate to what they wish to learn, but also to how they should learn it. This paper describes the Selector and LO Generator services of the iClass IST project and the approach taken to producing pedagogically sound personalized learning experiences using a standards based approach.

1 Introduction

In the past, Adaptive Hypermedia Systems (AHS) have attempted to customize courses to a learner's prior knowledge, goals and personal preferences without taking into consideration any form of pedagogy. As a result, such systems neglect the entire body of research that exists in the educational field and fail to take advantage of the benefits that the application of pedagogy has for the learning experience [Conlan and Wade, 2004]. iClass [iClass] is an open learning system which utilizes pedagogical strategies to adapt to learners' needs, intelligently and cognitively, and this paper will describe where the LO Generator and Selector services of iClass will deliver customized learning experiences. As part of the iClass Project, the Selector Service will be responsible for building a personalized path for a learner through a set of concepts. This is carried out in accordance with the learner's objectives and preferences while also taking into account the preferences of the teacher. The Selector Service will approach this problem by attempting to apply sound pedagogy to the courses produced in a similar way to systems such as APeLS [Conlan, et. al., 2002]. APeLS is an AHS that employs the Multi-Model, Metadata driven approach [Conlan, et. al., 2002], in other words APeLS maintains a set of models describing the necessary learner, content and pedagogical information which the system can then reconcile, at runtime, in order to generate a personalized course for an individual learner. The key advantage of APeLS is the separation of pedagogy from the adaptive system. This allows APeLS to utilize many different pedagogies.

Unlike APeLS, the proposed design for the Selector Service separates pedagogy and the description of the concept domain into two distinct entities. The concept domain is described in terms of a Concept Domain Ontology. This ontology describes the concepts that make up the domain as well as the relationships between those concepts. Ideally the concept domain ontology should be pedagogically neutral although this may not be realisable. If it is not possible to be completely neutral of pedagogy, the concept domain ontology should still be as pedagogically neutral as possible. Pedagogical neutrality of the concept domain ontology helps to reduce biases

towards a particular approach to teaching/learning, thus enabling the successful application of different pedagogies to the concept domain. Pedagogies are encapsulated in Pedagogical Strategies; these are sets of rules that determine what needs to be done, for each concept to be taught, in order to fit the concepts into a pedagogically based course. A Pedagogical Strategy should be considered as a high level guidance that may be applied to concepts or sub-concepts and is selected based on the teacher's and learner's preferences. By accommodating both the teacher and learner preferences in the selection of a pedagogical strategy the personalized course produced may fit both the teacher's preferred mode of teaching and the learner's preferred mode of learning.

The separation of pedagogy and concept domain brings several significant benefits, it speeds up the time taken to develop courseware and reduces the cost, as well as introducing a new axis of adaptivity upon which adaptation/personalization can occur. The time and cost reductions are brought about because pedagogies can be developed independently of the concept domains and vice versa. For example, a course developer (concept domain expert) does not require any specialist knowledge of the pedagogical strategies that could be applied to the concept domain they are developing. Further reductions in the expense of creating personalized educational courseware come from being able to reuse any pre-existing pedagogical strategy or domain ontology. Improved personalization is realised through the ability to apply many different pedagogical strategies to the same concept domain. This means that it is possible to adaptively select the most appropriate pedagogical strategy for a specific learner, irrespective of what they are learning, and so greatly enhancing their learning experience.

The iClass service that directly affects the generation of pedagogically sound personalized, context sensitive learning objects is a service known as the LO Generator. The function of the LO Generator is to select the most appropriate learning content from the learning object space, that corresponds to the specific content requested by the Selector, a service which selects the appropriate concepts to teach and an overall pedagogical strategy in which to teach them. The LO Generator interacts with various distributed information repositories using a variety of metadata formats and onthologies. The LO Generator will assemble appropriate LOs which will facilitate the teaching of each concept in the learning path created by the Selector, in a manner that is appropriate to the learning preferences of the learner. The Selector is responsible for adapting to the learner's prior knowledge and objectives, by selecting the appropriate concepts to teach, and for selecting an effective pedagogical strategy to teach them. The output of the Selector is a Personalized Learning Path (PLP) which contains a structure of concepts to teach the learner, coupled with pedagogical information on how they should be taught. It is the role of the LO Generator to create appropriate learning objects to instantiate the pedagogically influenced concepts in the PLP. The LO Generator also accounts for learner and contextual preferences in the generation of learning objects. In this way the Selector guides the overall pedagogical strategy of the learning, but the LO Generator personalizes towards the learner's preferences and current context.

The iClass system has a number of repositories that store and monitor various user and teacher models. When a teacher wishes to produce a course using iClass, they are given the option to specify the scope of the course across an existing concept domain and to specify the required learning outcomes for the course, among other things. After this initialisation, the Selector service comes into play, parsing the learner and teacher models together with the specified scope of the concept domain, producing a sub-domain, which is a subset of the original

concept domain. A pedagogical strategy is then required and is selected by the Selector again based on learner and teacher preferences.

This paper describes the workflow between the Selector and LO Generator services and describes the just-in-time generation of pedagogically sound, context sensitive personalized learning objects, based on personalized learning paths. Section 2 describes the reconciliation of multiple models towards the creation of a personalized learning path. Section 3 describes a worked example of how personalized learning objects are produced. Section 4 describes the standards and specifications most relevant to the Selector and LO Generator. Section 5 concludes the paper.

2 Reconciliation towards personalized paths

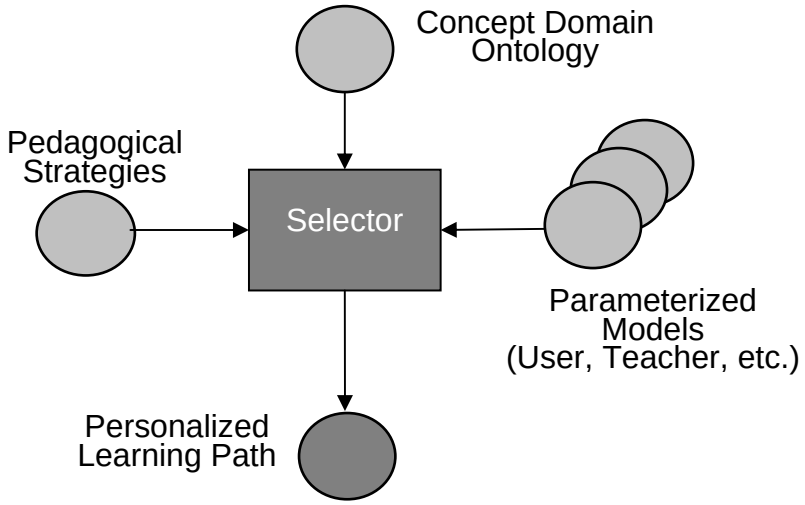

Figure 1, The Selector Service and its associated models.

As part of the iClass suite of services, the Selector Service is responsible for the reconciliation of an adaptively selected pedagogy with a given concept domain as well as the personalization of the produced course towards the learners prior knowledge and the teacher's and/or learner's desired learning outcome(s). The aim of the Selector is to produce a Personalized Learning Path or PLP. This 'path' describes the concepts selected as appropriate for the learner within the specified concept domain and within the context of a specific pedagogical model. In order to produce a PLP, the Selector must identify the needs and requirements of learner and the learner's teacher. This information is retrieved from the Learner Model and Teacher Model respectively. These models allow the learner and teacher control over key aspects of the Selector's workflow. It is, for example, through the Teacher Model that the teacher influences the pedagogical strategy applied by the Selector. Along with the Teacher and Learner Models, the Selector must have access to a set of one or more pedagogical strategies, from which it can make a selection, as well as the appropriate Concept Domain Ontology.

The Selector and LO Generator use a number of models to produce personalized learning objects. The learner model is used by both the Selector and the LO Generator. The Selector pulls information relating to pedagogical preferences and the prior knowledge of the user from this repository. The LO Generator makes use of this model to obtain information about the pedagogical preferences of the user.

The Selector takes information from the teacher model such as pedagogical preferences, teaching scenarios, a list of content types to be included or omitted. The Selector also takes information from the concept domain ontology and the repository of pedagogical strategies. The LO Generator uses information from the repository of contextual data, which stores information abut environment, device type, etc. The LO Generator also communicates with the actual learning object space, which provides access to the actual content needed for the generated course. This content is comprised of low level LO concepts, which don't necessarily make sense individually, but do when combined with other LOs.

As shown in Figure 1, and introduced in Section 1 of this paper, the Selector Service takes several input models in order to produce a PLP. Each of these models has a specific role within the Selectors workflow, these roles are as follows-

- **Teacher Model –** Provides the Selector with the teacher's preferences thus allowing the teacher to influence the Selector's selection of Pedagogical Strategy as well providing the Selector with the teacher's scoping for a particular concept domain.
- **Learner Model –** Provides information about the learner's preferences to the Selector.
- **Concept Domain Ontology –** This is a pedagogically neutral representation of a subject domain including the appropriate semantic relationships between concepts. It provides the Selector with a 'map' that will allow it to generate a path through the subject domain that is tailored towards the learner.
- **Pedagogical Strategy –** An expression of how pedagogy may be used to influence the creation of a PLP. The strategy will provide the Selector with a description of how concepts should be manipulated and arranged so that they fit into a given pedagogy.

In order to explore this strategy of reconciliation in greater detail, we will describe how the Selector Service will reconcile a specific Pedagogical Strategy with a concept domain. When the Selector is invoked, it first identifies the Concept Domain Ontology to be used and then sets about determining the constraints that the teacher wishes to apply as well as any learner preferences that can be used in the personalization process. The Selector first chooses the Pedagogical Strategy, for example a Case Study based approach, to be used and then uses the teacher's scoping conditions in order to produce a restricted view of the concept domain. This subset of the Concept Domain Ontology only contains the concepts that the teacher intends their students to cover. If the teacher does not specify any scoping conditions the Selector simply uses the entire Concept Domain Ontology. It is intended that the teacher will also be able to specify scoping conditions on a per student basis, if necessary. The learning outcomes (goals) that the PLP, produced by the Selector, should satisfy can be specified by either the teacher or, if the teacher so wishes, the learner. Once a subset of the concept domain has been created, by combining the scoping and required learning outcomes, the Selector then applies the chosen Pedagogical Strategy to it. This strategy has been selected primarily by reconciling the learner's learning preferences with the strategies available, but may also be influenced by the teacher's preferences.

The Selector will then apply the Pedagogical Strategy to the concept domain ontology by restructuring the relationships between the concepts and, where necessary, altering the relationships between concepts. It may also be necessary for the Selector to disaggregate concepts into sub-concepts in cases where the pedagogy requires. It is the Pedagogical Strategy

that informs the Selector about when and how concepts and the relationships between them should be modified and therefore these new relationships reflect the pedagogy being applied. When the Selector identifies an appropriate concept it queries the LO Generator in order to validate that concept. Validation of a concept by the LO Generator is carried out on the basis of available Learning Objects (LO), or Learning Assets that may be used to generate a new LO. If the LO Generator can provide an LO that teaches the concept in a manner that is consistent with the pedagogy being applied then the concept is considered to be validated. If an appropriate LO cannot be provided by the LO Generator, the concept is invalidated and the Selector must, either attempt to find an alternative path through the concept space that does not use the invalidated concept or apply an alternative Pedagogical Strategy that changes the way the concept is taught. The process of selecting a concept and validating it via the LO Generator is an iterative process whereby concepts are selected in turn in order to populate a PLP.

3 Producing Personalized Learning Objects – Worked Example

In the example of a case study, it is necessary for the Selector to restructure the concepts in a manner such that the structure of the concepts reflects the format of a case study. A generic case study might be broken up into the following parts: an introduction to the topic, contextual information, a problem statement, support/framework for solving the problem and an evaluation of the solution. In this scenario, the Selector would have to take the concept(s) and break them up, duplicate them or otherwise manipulate them so that each of the sections of the case study included the appropriate concepts.

For example, if a case based approach was applied to set of physics concepts the PLP may include *introduce Newton's Third Law, present the problem of colliding objects*, etc. In this case, *introduce* and *present problem* are elements of a pedagogical strategy. Fig 1, below, shows the interactions primarily between the Selector and LO Generator and their repositories. This section describes the workflow between the Selector, LO Generator and Presenter to produce a personalized learning experience.

As introduced in Section 1, teachers are given the option to specify the scope of the course across an existing concept domain and to specify the required learning outcomes for the course, when they start the construction of a course using the iClass system. At this point, the Selector service parses this teacher information, along with the learner information to produce a subset of the concept domain. A pedagogical strategy can then be selected by the Selector, again based on learner and teacher preferences. In our example, the concept domain is *Physics* and the sub-domain is *Newton's Third Law* and the chosen pedagogical strategy chosen by the Selector service is a *case-study*, which introduces a concept, presents a problem statement, provides resources to the learner and may provide an example solution.

The pedagogical strategy and the sub-domain are reconciled together by the Selector to create a narrative/PLP that consists of concepts and the pedagogical relationship between them. The prior knowledge of the learner will have to be taken into account at this stage; it makes no sense to describe something to the learner that they already know. Using this pedagogical strategy, the Selector may specify that the first LO on this PLP will *introduce Forces*. In this case *introduce* is an element of the pedagogical strategy being employed and *Forces* is the concept it is being applied to.

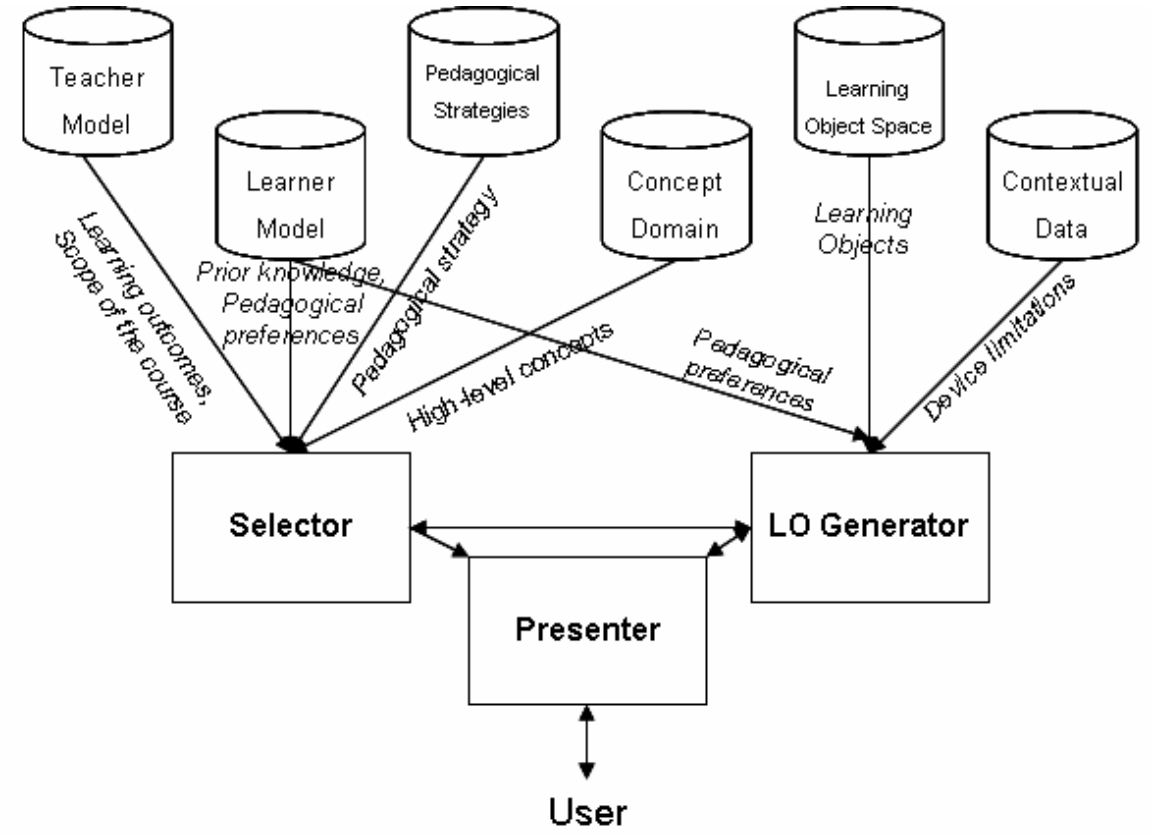

Figure 2, The iClass services and repositories involved in personalization

After specifying the first concept, the Selector makes a call to the LO Generator to check and see whether that concept exists in the learning object space. The LO Generator then assembles information about the learner, for example, in this case the learner prefers visual instruction (the use of diagrams, etc.), and contextual information, for example, this learner is using a black and white display PDA to access the course [Brady et al, 2004].

Using these additional parameters, the LO Generator now conducts a search of the learning object space to search for a learning assets that may be combined to fulfil all of the above requirements. It can make one of three return calls to the Selector service (1) the LO does not exist and no variation can be generated, (2) the LO does exist and (3) the LO does not exist, but an existing one can be morphed and returned. In this case, an LO exists that satisfies the pedagogical strategy and the visual preferences of the user. In order to fill the contextual needs, in this case the screen limitations of the device, the LO will have to be morphed, so the LO Generator sends back a return call citing option (3) above. The LO Generator caches the requested Los, for future delivery, as the process progresses.

After confirmation from the LO Generator, the Selector proceeds onto the next step in the pedagogical strategy, which is to state *Newton's Third Law*, and the cycle begins again, stepping onto the *definition of the law*, *examples that illustrate the law*, and *a quick test to see if the learner understood the law*. At the end of this, a full Personalized Learning Path (PLP) exists for teaching this concept to this learner through this concept domain.

The LO Generator has several options available to it in order to deal with the PLP. In the first case, a new service available in iClass needs to be introduced, the Presenter service, which will allow for just-in-time generation of personalized LOs. The Presenter is a service which can interpret the PLP and present the navigation embodied within the PLP. It can also invoke the LO Generator when necessary and in this case the LO Generator may deliver a cached LO. Another option available to the LO Generator is that it can deliver a complete content package with the personalized LOs and the IMS Learning Design [IMS LD] to govern their delivery. In order for the PLP to be effective, the LO Generator must fulfil all of the required aspects of the scenario or strategy embedded in it.

4 Relevant Standards and Specifications

As the iClass framework consists of many different services developed by different members of the iClass consortium, the interoperation of these services is an important consideration, as is interoperability with a broader set of eLearning services. One step that has been taken in order to facilitate this interoperation is the adoption of open standards and specifications. Another advantage associated with the use of open standards and specifications is improved communication between the partners in the consortium due to the common terminology they provide.

In the case of the Selector and LO Generator services, all of the models that they utilize, as well as their outputs, will be based on the relevant open standards. It is intended that the Concept Domain Ontology will be based on the W3C's OWL Web Ontology Language Recommendation [McGuinness, et. al., 2004]. OWL is intended to be used in cases where the meaning of terms and the relationships between them need to be processed by an application. The advantages of using OWL for the Concept Domain Ontology are that it is very expressive in terms of describing concepts as well as relationships; it also supports properties such as cardinality and equality. There also exist many tools that can be utilized in creating OWL ontologies. The PLP produced by the Selector will be based on the IMS Learning Design Specification [IMS, 2003]. Learning Design, LD, is a framework that describes the workflow of the teaching/learning process while supporting different kinds of pedagogical models and the personalization of learning activities [Koper, 2004]. LD does not restrict the use of pedagogies by prescribing a specific set of pedagogies, as the Selector will make use of many different Pedagogical Strategies this makes LD a suitable basis for the description of a PLP. LD also supports blended learning, i.e. the use of non-digital learning resources within the learning experience, this too is a feature of the iClass framework. LD will also facilitate the inclusion of decision points within the PLP (rules that are resolved at run time depending on the value of a property within the Learning Design). It is envisaged that decision points within the PLP will allow for dynamic adaptation towards the learner at run time. For example, the path taken by student might change depending on the result of a quiz that the student takes. This information could not be known when the PLP is being generated and so the decision point is left in the PLP to be resolved later. In the case of the LO Generator, its output will be in the form of IMS content packages with the relevant LDs and metadata included.

5 Conclusion

This paper has described the workflow between the Selector and LO Generator services of iClass and described the just-in-time generation of pedagogical sound, context sensitive personalized learning experiences. The Selector and LO Generator services described in this paper are key

elements of the iClass vision. The benefits of applying appropriate and sound pedagogy to a learning experience have been shown to improve the performance of the learner. In many existing AHS a 'one size fits all' approach is often taken to pedagogy. Such an approach cannot hope to address the needs of all learners, nor does it integrate well with every teacher's teaching methods. Enabling the teacher to personalize the pedagogical strategy applied to a course towards their own needs will allow the teacher to better integrate eLearning with their traditional classroom teaching. An added benefit of adaptive pedagogical strategies is that it gives the teacher the ability to tailor the delivery of a course towards individual student's needs. This can be advantageous if a student is not responding well to the traditional pedagogical approach to a subject domain and where they might benefit from an alternative strategy. The iClass IST project, funded under the European Commissions 6th Framework, is striving to provide educators and learners with a personalized learning environment built using pedagogically sound principles. The Selector Service described in this paper is a key element of the iClass vision.

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