Towards a Service Based Architecture for Assessment

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Abstract

In this paper we propose the outline of a service based architecture for bringing assessment techniques to open e-learning environments. We first describe a use case scenario for a generic assessment framework offering personalized assessment generation and then present its basic architecture as part of the Personal Reader Framework.
The generic assessment framework enables the search for the appropriate assessment resources after checking the learner's last saved performances and specific needs (e.g. language preferences, device requirements). In our assessment framework personalization functionalities are available as web services. The communication between these services is based on the Semantic Web technologies and does not need a centralized control. The assessment functionalities are defined in a separate Web service, which a user can subscribe/ un-subscribe as s/he likes.

1 Introduction

With the success of the World Wide Web, web-based learning systems become more and more dominant in the area of e-Learning. Successful learning systems for the Web require in particular solutions for effective assessment. Several Web based assessment systems have been developed such as Question Mark [Question Mark, 2004] and some others have been recently designed to carry out computer-based assessment, each system presenting different features [Qu et *al.*, 2001]. There is also a variety of Web-based courseware authoring tools that have inbuilt assessment modules, such as the Web course tool (WebCT) [WebCT, 2004].
In this paper we propose a generic assessment framework applicable for open e-learning systems which permit the dynamic processing and networking of heterogeneous resources, authored potentially by different people with different goals. Learning in open environments over distributed repositories demands effective personalization approaches to provide learner orientation and individualized access support [Brusilovsky and Nejdl, 2004], and requires advanced approaches for assessment which are capable of dealing with such distributed and open e-Learning environments. We claim that personalized assessment for open e-Learning environments can profit from recent research developments in the Semantic Web [Berners-Lee et *al*., 2004] in which machines can understand, process and reason about resources to provide better and more comfortable support for humans in interacting with the World Wide Web.
Effective assessment can not be a "one-size-fits-all" approach in which the same assessment strategy is applied to all learners. Learners are different. Some learners would need to be assessed on the whole learning materials, to evaluate their overall knowledge; others may need only to estimate their current knowledge at some steps of the learning process, in order to access the appropriate learning material. This requires also a flexible solution in which assessment strategies can be applied accordingly. We imagine an assessment framework in which different assessment strategies are offered as kind of services which handle all the necessary communication and reasoning for the assessment of some learner.
In this paper, we describe our vision of a generic assessment framework enabling personalized assessment services that the user can subscribe/ un-subscribe as he likes and investigate an architecture which integrates independent assessment and personalization services without the need of centralized control.
The paper is structured as follows: First, we motivate our work by a scenario of assessment in an open e-Learning network and its possible realization through a description of the resources and the reasoning rules over these resources with semantic web technologies. Our design of an assessment framework based on Semantic Web and facilitated by a Web service-based architecture is described in section 3. This architecture will be analyzed and discussed in section 4. After a comparison to related work in section 5 the paper ends with conclusion and remarks on future work.

2 Use case scenario for assessment in open e-learning environment

2.1 Scenario description

In this section, we will outline the context of our research with the help of a user scenario. Consider the following situation:
A computer science student Alice wants to prepare her exam on Java Programming course. She is registered in an e-learning network offering many computer science courses. For example Alice wants to review the lesson on classes in the course Java and to check her knowledge. Alice will select this lesson from the elearning network. Prequisites concepts will be first tested by searching and presenting to Alice the related questions. These questions

form the Pre-assessment test on the selected lesson. Alice will be then invited to visit the lesson parts that are not learned, for which the corresponding questions are not solved. Finally for ensuring that Alice understands the important concepts of classes in Java, questions will be searched and presented to constitute a personalized post assessment test on this lesson. The e-learning environment that Alice uses, keeps track on her progress in reviewing the course. Tests presented to Alice should provide an accurate estimation of her knowledge and will cover the important course parts that should be assimilated, in order to ensure that she can do without problem her final exam. Alice may select a lesson that she wants to review. The open e-learning environment should be able to search for the appropriate assessment resources after checking her last saved performances, her language preferences and device requirements.

2.2 Representation of the learning and assessment resources

To facilitate learning and assessment in our scenario, several functionalities need to be provided, to enable the search and exchange of heterogonous resources. It is necessary to handle various types of metadata for resources in an open network, describing learners, learning and assessment resources, information provided by the resources, as well as personalized assessment strategies.

Semantic Web technologies like RDF (Resource Description Framework) and RDFS (Resource Description Framework Schema) [RDF/RDFS, 2001] provide us with interesting possibilities to annotate resources, to enable an efficient personalization.

The java course lessons that represent the learning resources can be described through using the standards LOM (learning objects metadata) [LOM, 2002] and Dublin Core [DC, 2001]. The tests that will be selected to the learner based on his progress in the learning process can be described through the standard IMS/QTI [QTI, 2004].

We have annotated the online version of the Sun Java tutorial [Campione and Walrath, 2000], which is a freely available online tutorial on Java programming. Part of an RDF-description for a course on Java programming can be seen in the following example.

```
<rdf:Description
  rdf:about="http://java.sun.com/../class.html">
<rdf:type
  rdf:resource="http://ltsc.ieee.org/2002/09/
  lom-educational#LO"/>
<dc:title>What Is a Class?</dc:title>
<dc:language
  rdf:resource="http://www.kbs.uni-hannover.de/
  ~henze/lang.rdf#en"/>
<dc:subject
  rdf:resource="http://hoersaal.kbs.uni.han-
  nover.de/rdf/java_ontology.rdf#OO_Classes"/>
<lom-cls:prerequisite
  rdf:resource="http://hoersaal.kbs.uni.hannover
  de/rdf/java_ontology.rdf#OO_Objects"/>
  …….
<lom-cls:educationalObjective
  rdf:resource="http://hoersaal.kbs.uni.hann-
  ver.de/rdf/java_ontology.rdf#OO_Classes"/>
<dcterms:isPartOf
rdf:resource="http://java.sun.com/docs/books/
tutorial/java/concepts/index.html"/>
</rdf:Description>
```

As stated in the example above, the learning resources are described as learning objects, according to the LOM standard. The use of the attribute subject from Dublin core and isPartOf from Dublin core metadata terms permits respectively to describe the subject of the learning resource through referencing domain ontology, and to define the general organisation of the learning resources. Objectives and prequisites of each learning resource are introduced respectively with the properties lom-cls:educationalobjective and lom-cls:prerequisite based on a relationship with the domain ontology. The following example shows a question of the Java course annotated according to the standard IMS/QTI.

```
<rdf:Description>
  <rdf:about="http://java.sun.com/docs/books/
  tutorial/java/concepts/item1.html">
  <rdf:type
  rdf:resource="http://www.learninglab.de/~dolog/
  learnerrdfbindings/qti.rdfs#Item"/>
  <qti:itemmetadata>
   <rdf:Description>
   <qti:qmd_itemtype rdf:value="MultipleChoice"/>
  </rdf:Description>
  </qti:itemmetadata>
  <qti:presentation>   …….</qti:presentation>
  <qti:resprocessing>……..</qti:resprocessing>
  <dcterms:isPartOf
    rdf:resource="http://java.sun.com/docs/books
    /tutorial/java/concepts/index.html"/>
  <qti:title> MCOOP1 </qti:title>
  <qti:Objective
  rdf:resource="http://hoersaal.kbs.uni-
  hannver.de/rdf/java_ontology.rdf#OO_Methods"/>
</rdf:Description>
```

The selection of the questions, to be presented to the learner is based on its objective which is introduced through the attribute *objective*.

2.3 Reasoning over assessment and learning resources

In our scenario the exchange of RDF annotation enables a search of the appropriate resources and the personalisation of the learning process. The definition of rules permits reasoning over distributed annotations and communication within an open information environment.

A rule language for querying and transforming RDF models is TRIPLE [Sintek and Decker, 2002]. Rules defined in TRIPLE can reason about RDF-annotated information resources. TRIPLE supports namespaces by declaring them in clause-like constructs of the form *namespaceabbrev := namespace*, resources can use these namespaces abbreviations.

```
  java_course :=
      "http://java.sun.com/docs/books/tutorial".
```

Statements are similar to F-Logic object syntax: An RDF statement (which is a triple) is written as

subject[predicate →object].

The relationship between the assessment and learning resources can be established through the relation *question_of_resource*, which derives all related questions to a selected learning resource.

```
FORALL I, L  question_of_resource(I, L) <-
  question(I) AND learning_resource(L) AND
  EXISTS C ( concept(C)
             AND objective_of_question (I, C)
             AND  objective_of_resource(L, C)).
```

The second line in the rule above ensures that *I* is question and *L* is a learning resource (according to others rules that use the RDF annotations of the resources). The third line

is verifying that the objective (a concept of the ontology) of *I* is one of *L* objectives.

Assume that the student has e.g. selected the learning resource on java classes "*class.html*", the result of the previous rule is:

```
L = java_course:'java/concepts/class.html',
    I = java_course:'java/concepts/item1.html'
```

During runtime, the student interacts with the open learning environment. The user's interactions can be used to draw conclusions about user interests, user's knowledge, etc.

Assessment recommendations can be derived e.g. according to the following rules

```
FORALL L, U
 p_obs(L, U, PostAssessmentIsRecommended) <-
   learning_resource(L) AND user(U)
   AND EXISTS C (objective_of_resource(L, C)
   AND NOT (concept_learned(C, U))).
```

The rule permits to indicate that a post assessment is recommended for the current learning resource in case that at least one of its objectives hasn't been learned previously.

The rule for determining whether the student has learned some concept C (concept_learned(C, U)) is derived by checking the status of the related question to this concept and whether this question has been solved by this student, based on the information in his profile.

The results of these rules applied on learning and assessment resources of the Java Tutorial, will provide the student with the appropriate questions of the selected resources and evaluate the assessment status of each selected learning resource based on the learner navigation in the course and his saved performances.

According to our example, if we assume that the student has not solved e.g. question "item1", the result of the last rule (on the RDF- annotated and to Triple translated resources) is e.g. that for the user 'student' a post assessment on the resource 'class.html' is recommended:

```
U = 'student'
    L = java_course:'java/concepts/class.html'
```

3 Assessment Framework Architecture

Investigating our scenario in more depth, we see that assessment for learning resources have to take several issues into account: First, suggested assessment resources need to fit to learner´ language constraints, device constraints, costs, etc [Dolog et *al*., 2004]. Second a local and a global provision of the assessment resources is required in order to ensure an accurate assessment and knowledge diagnosis of the learner. Retrieved assessment resources need to fit to the current learner progress in the learning material. The selection and the generation of the assessment resources should be based on the saved learner performances. The same assessment material may be presented differently to the various learners based on their prior knowledge. At each step of the evaluation process the learner should be provided with the appropriate resource, either an appropriate question to estimate his knowledge or the lesson that needs to be visited.

Based on the above scenario, we can notice that there is a need of a generic assessment framework enabling a personalized assessment process in which the learner is provided with various functionalities, which he can choose independently. This framework should be able to

- Provide an infrastructure to request, search and select learning and assessment resources in an open network, and not from a closed corpus, appropriate to student knowledge.
- Deliver personalized tests appropriate to leaner knowledge through an adaptive search and presentation of assessment resources according to the learner previous performances and preferences.
- Provide an infrastructure to search and select the most appropriate evaluation scheme to the learner.
- Store results of evaluation, update and maintain learner data.

One of the driving forces behind the design of a generic assessment framework is to minimize the effort required to generate assessment functionalities over heterogeneous and distributed resources. This can be achieved through the design of a service oriented architecture, which is based on the notion of building applications by discovering and orchestrating available services and just-in-time integration of applications. Each component of this architecture is a service, which is usually independent from the others and which can interact with them by "understanding" the RDF notifications they send, through referring to semantics in the ontologies used in the RDF descriptions. This kind of exchange would promote the interoperability by minimizing the requirements for shared understanding and reduce the complexity of the functionalities thanks to services encapsulation.

Web services are Internet based distributed modular applications that provide standard interfaces and communication protocols aiming at efficient and effective service integration. Each Web service is a self-contained module of applications that has open internet-oriented, standards based interface [Alonso et *al*., 2004]. Each Web service can be called separately, and possesses its reasoning rules according to its offered personalization functionality.

In our solution we envision Web services capable of assessment and learning resources delivery with respect to domain ontology, learners' requirements and interaction with the learning environment. The assessment framework offers a dynamic binding of its components, as services for providing the user interface, for mediating between user requests and available personalization goal. This architectural outline for implementing the assessment framework is a rigorous approach for applying Semantic Web technologies. Indeed, the communication between the different Web services is through RDF documents. The RDF descriptions reference to ontologies, that permit the search and the presentation of the needed information.

Learner´ authentification is realized through the login service, which enables to check the learner parameters and to send them to the other services. The visualization service is responsible on the display of the resources, requested by the learner, either the learning resources or the assessment resources. The communications between all services, except for the login service, goes through the connector service by exchanging of RDF descriptions. E.g. the request for getting a test for assessing the knowledge of a certain user is provided by an RDF description which is exchanged between the connector service, which is the component mediator and the assessment service.

The main task of the Connector Service is the conversion between the different formats of metadata descriptions used by each Personalization Service.
The architecture of the whole framework is presented in the following figure. In the next section we will describe the user profile service and some personalized services offered by the system.

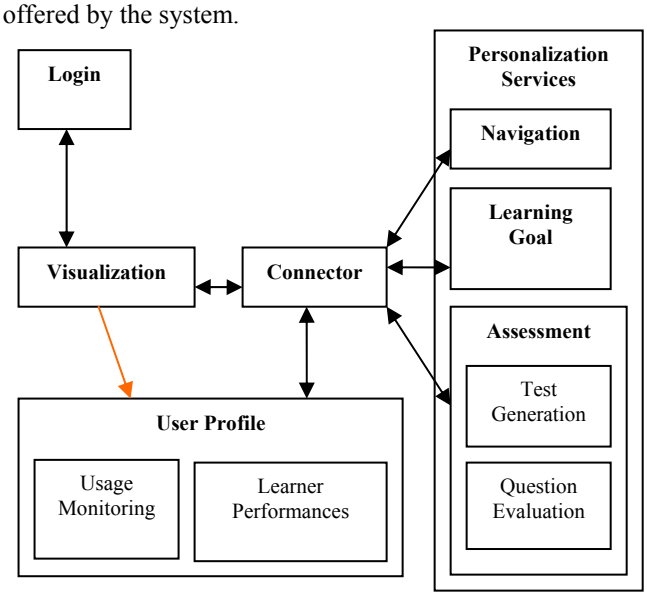

Figure 1: Architecture for assessment framework

3.1 Navigation Service

A *navigation service* provides personalized navigation maps of resources for the learners based on the information provided by the learner profile. This service offers two kinds of Maps: a Lesson Map, which contains the lessons that are already visited or recommended for the learner and a Test Map that permits to have an overview on the selected questions and the status of their evaluation. Approaches based on concepts mapping [Gouli et *al*., 2003] for organizing learning and assessment concepts in a hierarchical manner and forming meaningful relationships between them can be used.

3.2 Learning goal service

The *learning goal* service provides an annotation of the resources based on the information provided by the learner profile. This information contains the last saved learner performances; the generation of the annotation is based on predefined rules that permit the calculation of the next recommended learning goal for the learner. The results of calculation are given to the navigation service to enable a generation of personalized navigation Maps.

3.3 Assessment Service

The *assessment service* is the most important and complicated service in the architecture. It is composed of two others services that can be requested independently: the test generation service and the question evaluation service. The role of the assessment service is to provide a personalized assessment to the learner based on the information provided in the learner profile. The first component of this service, the test generation service is responsible for the construction of tests. A test is typically a well-organized sequence of questions selected adaptively based on the learner profile provided by the connector service. Several types of question can be deployed in a test in order to evaluate the level of knowledge acquisition of the learner. The second service is the question evaluation service, which is in charge of assessing learner answers to presented questions. The result of this evaluation is an RDF document, which will be submitted via the connector service first to the user profile service in order to update the learner profile and then to the visualization service in order to display the results of the evaluation.

3.4 User Profile Service

The *user profile service* permits the generation of a learner profile based on the last saved learner' interactions and answers to the proposed tests. It is composed of two services the usage monitoring service and the learner performance service. The first service permits to save information on the user interaction with the learning and assessment resources. The second service, the learner performance service permits to update the information on the learner knowledge based on the results of the presented questions which are received from the assessment service via the connector service. After each user request, the user profile service provides the connector service with the learner profile, which contains information on the leaner historic progress.

4 Architecture analysis and discussion

We have outlined the architecture of a generic service based assessment framework in an open e-learning environment. This architecture can be an effective mean to provide personalized assessment in such environments.
Some adaptive systems would allow the learner to directly select and browse the needed learning materials [Brusilovsky and Paylo, 2003]. However these systems are unable to diagnose the learner learning goal and prior knowledge based on his browsing. Furthermore, in some adaptive tutoring systems the student may have a predefined test allowing the extraction of a model from a domain knowledge [Brusilovsky and Paylo, 2003]. However this predefined test can not estimate correctly the exact knowledge of the learner and provide him with the appropriate learning materials. A personalized assessment service is needed to search for the appropriate assessment resources and to generate a test for the learner that is personalized to his profile.
By combining efforts of Web services and Semantic Web technologies, we expect that new mechanism for enabling generic discovery, access, combination and management of assessment resources will be developed. Our architecture of reusable components, supports the shareability and the interoperability of the components as well as the use of others components within an open system. These components defined as Web services use the semantics of the data and offer means for flexible services composition through automatic selection, interoperation of existing services, verification of service properties and execution monitoring. The framework is able to reason about the functionalities provided by different Web services, to locate the best ones for solving a particular problem and to automatically compose the relevant Web services for dynamic application building.
The learner wants to know whether he has good assimilated for example, the lesson on the "class" concept in

Java. He will send a query via the visualization service asking for a test containing assessment resources related to the selected lesson. This request will be enriched with learner profile information, such as his previous registered performances on this course (in case he already has been assessed on some other learning resources regarding the same course) and information on his preferences such as the teaching languages, styles, device, etc. The requested learner profile will be provided by the user profile service responsible on the registration of learner preferences, interactions and saving learners previous performances.

A personalized test will be then generated by the test generation service, by searching and highlighting the needed assessment resources related to the selected course, which is in this case Java. The learner will then retrieve from the e-learning environment the assessment resources (questions) in his preferred language, to estimate his knowledge on the "class" lesson. Questions will be presented adaptively to the learner. Based on the learner answer, the assessment service will send to the learner the next appropriate question. Once the learner answers a question, this interaction will be first recorded by the user profile service. A query containing the learner profile and the learner answer will be send to the personalized assessment service. The latter send this query to the evaluation service responsible for searching of an evaluation scheme for the answered question. In case the student score is acceptable, he is able to access the lesson on the "class" topic. Once he finishes reading again this topic, he will be given another test with assessment material from other online courses, related to the "class" lesson.

The learner can also be provided with the context of the assessment and learning resource in a course. This functionality is provided by the navigation service. At any step of the assessment process the learner may also ask for a calculation of his next learning goal based on recommended assessment resources. This functionality is provided by the learning goal service. Hence, this service oriented architecture provides a personalized assessment through the encapsulation of several functionalities, enabling their interoperability and their extensibility. To enable learner support in the generic assessment framework as described in our example scenario, the described Web services require meta-information about courses, learning resources, and about learners. The framework ensures the interoperability between these resources by using of RDF descriptions based on well-defined RDF schemas and learning specific standards to support interoperability.

5 Related work and discussions

In our work, we propose a personalized assessment framework based on an open and modularized architecture, able to interact, exchange data and share components. Related work to our approach includes Web service based systems, enabling personalization functionalities and assessment systems. In [Henze and Kriesell, 2004] the Personal Reader Framework is presented. It is based on the idea of establishing personalization functionalities services on the Semantic Web. Our presented architecture is part of the Personal Reader framework. The assessment service is currently tested as a new personalization service of the Personal Reader Framework. Furthermore the services presented in our architecture will be also implemented as value added services according to [Brusilovsky, 2004]. Personalization in assessment systems has been already discussed in the framework PASS [Gouli et *al*., 2002] aiming to estimate learner's performance and to assess specific learning outcomes, which are congruent with the learner's learning goal. Comparing our work to the PASS framework, we observe that the architecture of this system incorporates relatively many components (subsystems), which are very dependent. We need to replace the current models of assessment architecture design with a more flexible architecture. A key point in our architecture is the fact that the proposed assessment framework is generic thanks to the encapsulation characteristic given by the assessment service, which permits to reduce the complexity of this service and permits its interoperability and extensibility.

The interoperability in some assessment systems such as Questionmark Perception [Question Mark, 2004], the question authoring facility in WebCT and the CETIS rendering Tool [CETIS, 2004] has been analyzed in [Sclater et *al.*,2002]. The criteria used for evaluation were: the ease for questions creation, the ease and the accuracy with which these systems export the questions into the IMS QTI standard [QTI, 2004] and the importation aspect in these systems. This evaluation has shown that it is possible to transfer simple questions using an internationally agreed format among a variety of assessment systems [Sclater et *al.*,2002].

The idea of combining Web services with assessment tools has been introduced in [Brusilovsky et al., 2003], where a QuizGuide service is described as an adaptive service for presentation of most relevant quizzes offered by QuizPack system [Sosnovsky et al., 2003]. However this system focuses only on one type of questions which are the parameterized question. In the proposed framework, we propose to the learner two kinds of questions, the multiple choice question and questions defined as programming code with missing instructions. Furthermore, we propose an assessment service based on adaptive selection of question. The enhancement of the assessment process with adaptive capabilities enables indeed dynamic and individualized process, as it is adapted to the learner's performance, and reduces the number of questions required to estimate learner's knowledge level, resulting in a less tedious assessment process. Systems, like SIETTE [Guzman et *al*., 2004] and AthenaQTI [Tzanavari et *al.*, 2004], offer adaptive assessment generation, based on the IMS/QTI standard. SIETTE seeks to improve computerized Adaptive Testing, where AthenaQTI focuses on authoring of personalized assessments according to QTI standard. While these systems have some goals in common with ours, their focus is clearly on adaptive assessment processing and not on adapting learning content presentation and on recommendation calculation required for an adaptive learning. Besides, their architecture is not flexible enough to provide a generic assessment generation. Moreover we propose in our architecture a user profile service, for the generation and the maintaining of the user profiles. Approaches for user modeling for personalized learning are discussed in [Denaux et *al.*, 2004].

6 Conclusion and Future Work

We have presented service oriented architecture for a generic assessment framework, enabling a personalized assessment in open e-learning environment.
As next step we aim to test the generic assessment framework as part of the Personal Reader Framework (www.personal-reader.de) and to evaluate it for online courses annotated based one-learning standards, with respect to learning support, learners' acceptance and reusability aspects.

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