Reasoning about learning object metadata in the Semantic Web

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Overview

- This work is focussed on the problem of bringing **adaptation** in the selection and composition of **learning resources** distributed on the semantic web
- **Learning resources in the semantic web**
  - adding a semantic layer to the description of (learning) resources accessible over the internet.
  - taking into account current proposals of standardization of learning object metadata -> SCORM courseware
  - enabling the application of automated reasoning techiques for personalized use and reuse (-> REWERSE).
- **Adaptation by reasoning**
  - lessons learned from the literature on AH applied to the educational issue -> the knowledge level

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- **Adaptation by reasoning**
  - lessons learned from the literature on AH applied to the educational issue -> the knowledge level
- **Our contribution**
  - We add a semantic layer to the SCORM framework (IEEE LOM based) 1. annotation of learning resource -> prerequisites-effects; 2. learning strategies
  - We apply curriculum sequencing techniques from AH (planning) for generating on-the-fly personalized SCORM-based courses combining annotated learning objects

Semantic Web & education

- The Semantic Web [Berners Lee & al] is concerned with adding a computer-interpretable semantic level to resources that are accessible over the internet in order to enable sophisticated forms of automatic use and reuse.
- Resources are not all of a same kind: HTML document; web services : software that can be invoked over the internet
- Semantic markup of resources to enable automation: DAML+OIL and OWL for documents; OWL-S for web services.
- Automated reasoning on the semantic web -> REWERSE
- Especially with the development of peer-2-peer e-learning architectures, also learning objects can be considered as resources that are accessible over the internet: Aroyo 2003.
- Given a proper semantic markup we can apply reasoning techniques to support automated and personalized learning object discovery, selection, composition

AH & curriculum sequencing

- Wide literature on Adaptive Hypermedia applied to educational issues
  - a great number of Web-based systems based on different, adaptive and intelligent technologies : ELM-Art, the KBS hyperbook system, TANGOW, and many others
  - common goal: using knowledge about the domain, the student and the learning strategies in order to support flexible, personalized learning and tutoring
- curriculum sequencing: one of the technologies used in Web-based education for supporting adaptation and guidance, where an *optimal* reading sequence through a hyper-space of learning objects is to be found
  - different methods on how to determine which reading (or study) path to generate in order to support in the best possible way the learner navigation through the hyper-space.

AH & curriculum sequencing

- Lesson learned: the knowledge level
  - to keep separate
    - the knowledge entities (competences) and , i.e. some identifiable piece of knowledge related to the learning objects, and
    - the information entities (that is the actual learning objects).
  - to define at the knowledge level, a set of learning dependencies = the dependencies among knowledge entities
  - Given such a separation
    - associating to each learning object a set of competences that describe it
    - adding to the system an adaptation component
      - it can use knowledge associated to the learning objects **&** a representation of the user learning goal **&** of the user knowledge, for performing the **sequencing task**
      - generated sequences fit the user requirements and characteristics, based on the available learning objects.

Working at the knowledge level

- Advantages
  - it is closer to human intuition
  - easy reuse of the learning objects: the same learning object will be automatically taken into account by the adaptation component whenever a competence that is supplied by it is necessary during the sequencing process.
  - it enables the application of reasoning processes for implementing adaptive sequencing
    - the WLog system
    - previous work [Baldoni, Baroglio, Patti, AIRE 2004, Kluwer]

Adaptation by reasoning - WLog

- **action metaphor**: a learning object is an **action** with
  - a set of preconditions (knowledge that is necessary for using the learning object)
  - a set of effects (the supplied knowledge).
- an action can be executed given that a set of conditions holds; by executing it, a set of conditions will become true; in the same way a learning object can profitably be used if the learner has a given set of prerequisite knowledge; by using it, the learner will acquire a new set of knowledge.
- a tutoring agent (reasoner) uses such descriptions **&** the user learning goal (expressed in terms of knowledge) for performing the sequencing task.

Adaptation by reasoning - WLog

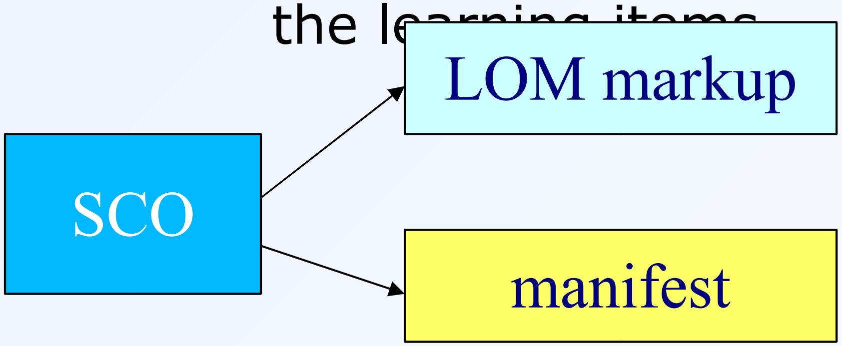
- sequencing by refining learning strategies (schemas)
  - described on the basis of the defined knowledge entities
  - decoupled from the actual learning objects.
- reasoners are implemented in the logic language DyLOG [Baldoni,Giordano, Martelli, Patti, AMAI 2004, Kluwer]
- reasoning techniques from reasoning about actions: planning, temporal projection, and temporal explanation
- reasoning about the dynamics of the learning objects outcomes and preconditions and generating sequences of learning objects for achieving the learning goal.

SCORM

- Frameworks using standard learning object metadata: there already exist various proposals for standardizing the description of learning objects, to make them cross-platform (cross-LMS, learning management systems).
- One of the most interesting frameworks is **SCORM** (new version 1.3. - http://www.adlnet.org/)
- Why SCORM?
  - it is a standardized framework;
    - it describes LO's (IEEE LOM - Learning Tech. Standard committee) AND
    - it also rules their presentation into a course

SCORM

- SCORM terminology: learning units (atomic or composed) are called SCO
- Each SCO
  1. can be annotated by adding a description in terms of IEEE **LOM** (Learning Object Metadata)
  2. has a **manifest**
     - describing the structure of the SCO (it can be composed by items)
     - including the **rules that govern the presentation** of the learning items



SCORM & the manifest

- SCORM manifests allow to rule the presentation of learning objects

- The language by which rules for presenting the learning elements are written basically exploits simple operators like sequencing, if-then branching.These operators allow the description of a learning object as a tree in which inner nodes (items) represent sub-activities. The tree leaves are the single units (assets) of which the learning object is made (e.g. a set of HTML pages).

SCORM & LMS

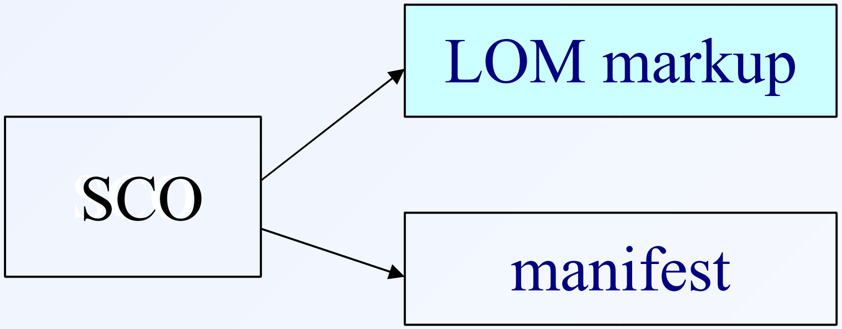
- The decision by which the next item to show is taken by the Learning Management System (LMS), based on
  - the rules contained in the manifest
  - features that depend on the actual user behavior (e.g. the user has read the previous item, the user has not answered a question correctly).

- Nice point: modularity of this representation
  - learning objects can be composed, they can be reused in many compositions,
  - reuse can occur at any level, so composed learning objects can be reused as well as a whole

- **Great potential in the idea of using the manifest BUT adaptive generation of courseware is limited:**
  - the manifest is not dynamically generated;
  - adaptation currently offered is very simple, based exclusively on the navigation behavior of the user

EXT1: LOM markup at KL

- LOM: a complete LOM description consists of attributes;
- Attributes: nine categories (general, life cycle, meta-metadata, technical, educational, rights, relation, **classification**, and annotation)
- EXT1: Annotating LOM at the knowledge level
  - Classification attribute: includes the possibility of describing the contents of a learning object in terms of keywords taken from an ontology of interest -> by means of LOM it is possible to include in a SCO a description at the level of knowledge entities



EXT1: LOM markup at KL

- Aim: introducing at the level of the learning objects some metadata describing their prerequisites and effects as in curriculum sequencing application
- Proposed annotation by the LOM classification attribute:
  - it allows the annotation of the learning objects by means of an ontology of interest
  - it consists of a set of ontology elements - **taxons** -> our knowledge entities
  - taxons have an associated role: the **purpose**;
  - purpose's value specifies if the annotation refers to a **prerequisite** or to an **educational objective** of the learning object
  - taxons can be part of a standard ontology (i.e. ACM computer classification system)

The proposed annotation: example

```xml
<lom xmlns="http://www.imsglobal.org/xsd/imsmd_v1p2"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.imsglobal.org/xsd/imsmd_v1p2 imsmd_v1p2p2.xsd">
  <general>
    <title>
      <langstring>module A</langstring>
    </title>
  </general>
  ...
  <classification>
    <purpose>
      ...
      <value><langstring>Prerequisite</langstring></value>
    </purpose>
    <taxonpath>
      <source>
        <langstring>http://daml.umbc.edu/ontologies/classification.daml</langstring>
      </source>
      <taxon>
        <entry>
          <langstring xml:lang="en">relational database</langstring>
        </entry>
      </taxon>
    </taxonpath>
  </classification>
  ...
  <classification>
    <purpose>
      ...
      <value><langstring>Educational Objective</langstring></value>
    </purpose>
    <taxonpath>
      <source>
        <langstring>http://daml.umbc.edu/ontologies/classification.daml</langstring>
      </source>
      <taxon>
        <entry>
          <langstring xml:lang="en">scientific databases</langstring>
        </entry>
      </taxon>
    </taxonpath>
  </classification>
</lom>
```

Fig. 2. Excerpt from the annotation for the learning object 'module A': "relational database" is an example of prerequisite while "scientific databases" is an example of educational objective.

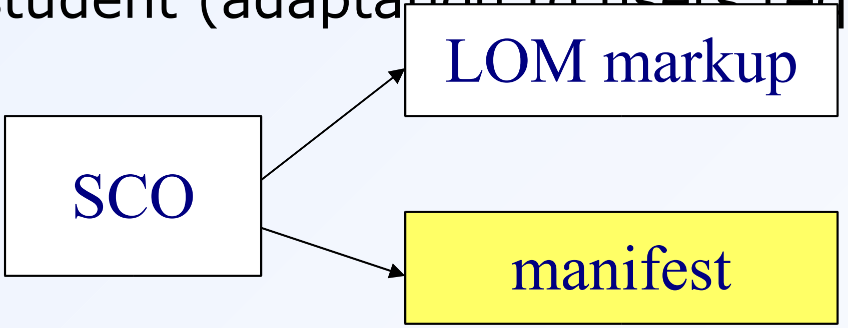
Taxons from the DAML version of the ACM computer classification system ontology.

Reasoning by planning

- The proposed annotation expresses a set of learning dependencies in terms of knowledge entities. It supports the interpretation of a learning object, written according to the SCORM framework, as an action having precondition and effects, and then opens the way to the application of standard Artificial Intelligence reasoners for performing various tasks.
- it is possible to compose reading sequences by using the standard planners -> Graphplan, a general-purpose planner that works in STRIPS- like domains;
- **problem**: general-purpose planners search a sequence of interest in the whole space of possible solutions and allow the construction of learning objects on the basis of any learning goal
- this is not always adequate in an educational application framework where the experience of the teachers, in structuring the courses and the learning materials, is important e limits the possible combinations *ab ovo*
- introducing learning strategies

EXT2: learning strategies at the KL

- Learning strategy:
  - a rule (or a set of rules) that specifies the overall structure of the learning object, expressed only in terms of knowledge entities
  - the description of a manifest at the knowledge level
- The construction on the fly of a learning plan is obtained by refining a learning strategy
  - according to specific requirements (guidance of the teacher) &
  - by choosing those SCOs, that are the most suitable to the student (adaptation to users requirement.



Example: DyLOG

no reference to specific learning objects is done

$$
\begin{aligned}
&strategy('informatics\_for\_biologists')\ \textbf{is}\\
&\quad achieve\_goal(has\_competence('computer\ system\ organization')) \wedge\\
&\quad achieve\_goal(has\_competence('operating\ systems')) \wedge\\
&\quad achieve\_goal(has\_competence('database\ management')).\\
&\quad \ldots\\
&achieve\_goal(has\_competence('database\ management'))\ \textbf{is}\\
&\quad achieve\_goal(has\_competence('relational\ databases')) \wedge\\
&\quad achieve\_goal(has\_competence('query\ languages')) \wedge
\end{aligned}
$$

$$
\begin{aligned}
&access(learning\_object('module\ A'))\ \textbf{possible if}\\
&\quad has\_competence('distributed\ database') \wedge\\
&\quad has\_competence('relational\ database').\\
&access(learning\_object('module\ A'))\ \textbf{causes}\\
&\quad has\_competence('scientific\ databases').
\end{aligned}
$$

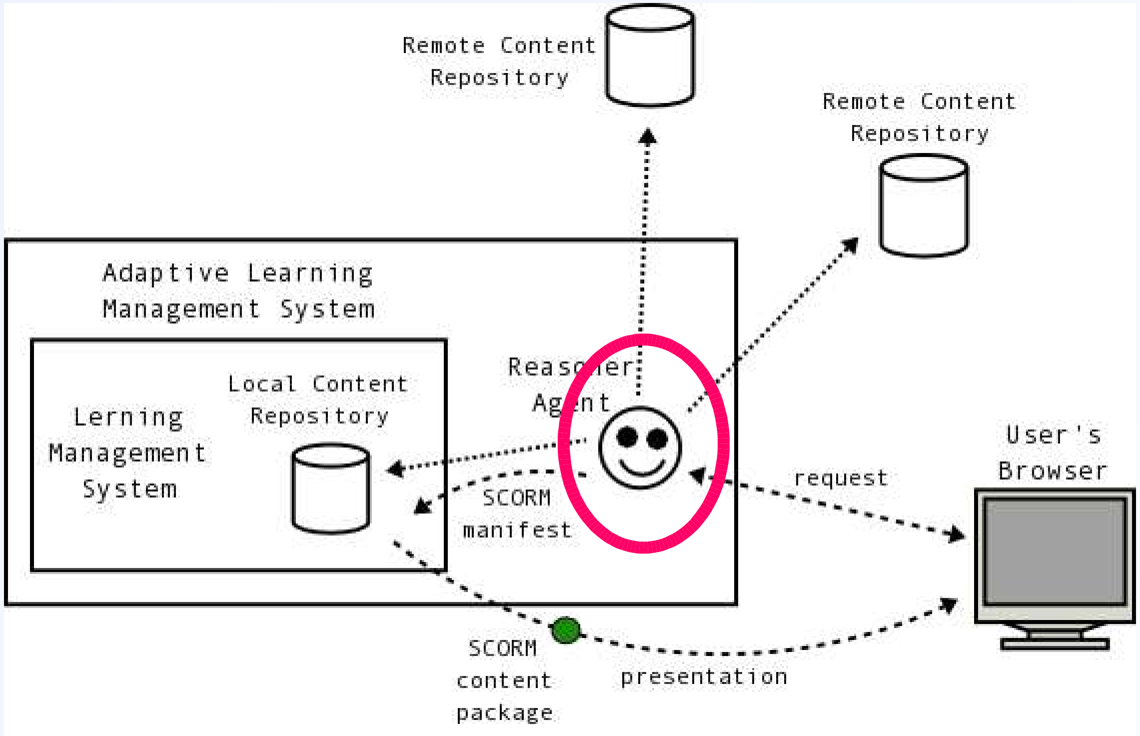
- **learning strategies as declarative DyLOG programs**
- **all possible executions satisfy the learning goals of the strategy**
- **adaptation: selecting an execution that also satisfies the user's requirements**

Learning strategies & procedural planning

- Given a DyLOG learning strategy, it is possible to apply procedural planning for refining it and possibly assemble a new learning path made of SCOs, that are annotated with the competences, suggested by the strategy.
- Opposite to general-purpose planners, procedural planning searches for a solution in the set of executions of a learning strategy.
- Important: since the strategy is based on competences, rather than on specific resources, the system might need to select between different courses, annotated with the same desired competence, which could equally be selected in building the actual learning path.
  - This choice may be derive from a further interaction with the user or can be done based on external information, such as a user model

Extending LMS

- All these steps should be carried on by the intelligent component added to the LMS architecture.
- The resulting plan can be stored as a SCORM manifest, which can be considered as an instance of the original learning strategy.



Conclusion & future work

- Decoupling the strategies from the learning objects in a greater flexibility of the overall system, is a fundamental key for opening the way to Semantic Web scenarios, where learning resources are distributed over the network and reasoning systems make use of semantic annotation for automatically selecting and composing them, according to the user's needs.
- Advantages: a greater ease of reuse of the learning objects, and on the possible (partial) automatization of the construction of ad hoc learning objects.
- Also learning strategies could be made public and shared across different systems
- Different declarative languages for the representation of learning strategies (workflow?)