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Cristea, A.I.

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What can the Semantic Web do for Adaptive Educational Hypermedia?

Alexandra I. Cristea
Faculty of Computer Science and Mathematics
Eindhoven University of Technology
PO Box 513, 5600 MB Eindhoven, The Netherlands
Tel: +31-40-247 4350
Fax: +31-40-246-3992
a.i.cristea@tue.nl

Abstract
Semantic Web and Adaptive Hypermedia come from different backgrounds, but it turns out that actually, they can benefit from each other, and that their confluence can lead to synergistic effects. This encounter can influence several fields, among which an important one is Education. This paper presents an analysis of this encounter, first from a theoretical point of view, and then with the help of LAOS, an Adaptive Hypermedia (authoring) framework that has already taken many steps towards accomplishing the goals of the Semantic Web. Here we also show how the LAOS framework, and more specifically, its implementation, MOT (My Online Teacher), can be re-written in Semantic Web languages, as an exercise of bringing Adaptive Hypermedia and the Semantic Web closer together.

Keywords
Authoring of Adaptive Hypermedia, Adaptive Educational Hypermedia, XML, XML Schema, RDF, RDF Schema

Introduction

The Semantic Web (WC3) (http://www.w3.org/2001/sw/) can be said to be, from a constructivist point of view, all about authoring. That is manually or automatically labelling the pieces of information with semantically rich annotations which can be further interpreted automatically by agents or other (Web) programs. This interpretation – or reasoning – is done based on Ontologies (Mizoguchi, 2004).

Adaptive Hypermedia (AH) (Brusilovsky, 2001a) is the solution to the problem of personalization on the Web, especially for Educational Systems. Adaptive Educational Hypermedia (AEH) (Brusilovsky, 2001b) caters to the needs of each individual student, adapts to their goals (Clifford, 2000); knowledge level (De Bra, & Calvi, 1998); background, interests (Brusilovsky et al., 1996); preferences (Höök et al., 1997); stereotypes (Zakaria & Brailsford, 2002); cognitive preferences (Chen & Macredie, 2002) and learning styles (Stach et al., 2004).

What can the Semantic Web bring to adaptive hypermedia that AH doesn't already have? Nothing at a first glance, at least not with respect to the richness of adaptation available for each student. However as we shall see, this view changes if we talk about the scale of the adaptation; about the extent of information accessible for adaptation and about personalization between different systems.

The Semantic Web comes with new emerging standards based on evolving Web technologies, that allow the reuse of material in different contexts, flexible solutions, as well as robust and scalable handling.

Again, what does this bring to AH? It is true that traditional AH has been kept within a non-flexible framework working within given parameters for each system. Therefore, flexibility is one characteristic which AH can borrow from the Semantic Web. As we shall see, there are others.

Intelligence in AH was typically hidden within the delivery engine, and authoring tools worked with specific systems only. Recently however, authoring of Adaptive Hypermedia has moved towards generic authoring principles (Cristea & Mooij, 2003a), based on semantically labelled reusable material (services, as in Conlan et al.,2003; or relationships, as in AHA!, as described by De Bra et al., 2003a), even towards semantic labelling of behaviour (Cristea & Calvi, 2003).

The real solution comes, as previously hinted, from addressing the question of interoperability between different systems and interfacing. Previous experiments (e.g., Stewart et al., 2004) have shown that a "common language".
a common denominator, is extremely important, so that the semantics can be preserved between different systems. It is at this level where the actual acceptance of standards by the different parties (authors, researchers, developers, end-users) becomes important, even if the standards might not fulfil all of their respective needs. Before we proceed, we have to analyse these needs in more detail.

The remainder of this document is structured as follows. First we look at Adaptive Hypermedia and the Semantic Web from the point of view of E-learning, to see if and how E-learning can benefit from them. The next section treats the adoption process of Semantic Web techniques and technologies by Adaptive Hypermedia. We then shortly sketch LAOS, an Adaptive Hypermedia (authoring) framework, along with its goals and connection to the Semantic Web. Then we consider LAOS from the point of view of Semantic Web languages, and attempt to express it in XML Schema paired with an example XML application. Next we describe MOT, an authoring system built based on LAOS. We look at some Semantic Web features of MOT, and we then express MOT in the Semantic Web language, RDF. Finally, we draw some conclusions.

E-Learning, Adaptive Hypermedia and the Semantic Web

Do the Semantic Web and Adaptive Hypermedia actually provide viable solutions for e-learning? Fensel & Musen (2001) call the Semantic Web a “bigger and more powerful” Web — but what can the Semantic Web do for e-learning? According to Brusilovsky (2001) “Adaptive Hypermedia is an alternative for the ‘one-size-fits-all’ approach in the development of hypermedia systems”. How does this benefit e-learning? As both Adaptive Hypermedia and Semantic Web have higher production costs than regular, linear hypermedia for e-learning, the benefits have to be evaluated carefully.

What are these benefits? Before embarking on one or the other solution, an educator or provider of “learning” (e.g., as a commodity) should consider the following questions:

1. Do I only deal with learners of a given type (as opposed to a variety of learners and learner characteristics)?
2. Do I need to change (parts of) the content frequently or do I expect to perform changes in time to the given material (as opposed to not at all)?
3. Do I expect everything to be created by the same person, an expert who can deal with all aspects of a course (from contents to the adaptive behaviour, from notification type to other communication aspects, etc.), as opposed to having different experts and roles for different parts of the authoring / creation process?
4. Do I need to export (move data) between different learning systems, as opposed to using only one system during the whole authoring and exploitation (learning material delivery) process?

Let’s look at the possible answers and treat the needs resulting from them one by one.

Learners of a given type

If the answer to the first question is yes, then adaptivity is most probably not the answer, and a one-size-fits-all approach is appropriate. There are some special cases in which learners of a given type still vary (for instance, in time) with respect to their needs, preferences, etc., but here we are considering a setting similar to that of educational TV broadcasting, without any type of personalization.

If the answer is no, and there are several types of learners, then Adaptive Educational Hypermedia is necessary, to cater for the different needs for each type of learner (for instance, for each stereotype, such as beginner, intermediate, advanced; or for each learning style expected, such as field-dependent and field-independent). The semantic web responds with user ontologies, but their actual applications still lie in the future.

Frequent content change

If the answer to the second question is yes, then the content has to be sufficiently malleable to be reused in different settings, so that each change can focus on the new issues and refine the old. Therefore, a layered approach with appropriate semantic labelling is necessary, at least with respect to the semantics inherent to the e-learning system used. The layers should reflect a higher level semantics, such as domain model, user characteristics, machine characteristics, etc. At a lower level, the semantics have to be applied all the way to the
lowest level of reuse. So, for instance, if a paragraph can be reused, it should be appropriately labelled in order to be easily retrieved according to its semantics. Using semantic standards is of benefit in this case but not a necessity per se. Note that this semantic labelling is necessary even if the same person will be making the changes, in just the same way that programmers add comments to their code even if they will be the ones who will do the updates later.

If the answer to the second question is no, then there is no need to conform to standards or to any type of layered architecture. If one-time-creation is enough, and no changes are expected, then no special care has to be invested in order to semantically label the contents in any way.

**Single author versus collaboration**

If the answer to the third question is yes, then there is no particular need to do a grouping (and semantic labelling) of resources according to the role the user is playing. Indeed, most learning systems have only one role in mind, the learner. Even more popular are the systems targeting two roles: the author and the learner. For the latter, the author will be responsible for creation and production of everything the learner needs, in a perfect producer-consumer cycle. Adaptation may only be useful if the learners are of different types or if frequent changes occur (see previous questions), otherwise not. Similarly, added semantics, or standards, are not necessary for the simple systems described above.

However, if the answer is no, i.e., more authors are involved, doing the same or different tasks, or if more roles are involved, appropriate semantic labelling becomes crucial, and the use of internationally accepted semantic standards is beneficial for the scalability of people and roles involved.

For instance, the PROLEARN initiative (http://www.prolearn-project.org/), targeting mainly corporate e-Learning, has identified as many as five different roles in a generic learning system, given here with their description as proposed by several PROLEARN members:

- **learner:** A learner can be in different stages of his/her career, and thus also have slightly different needs. For instance, the learner can be a high school student with no idea about his/her future in terms of studies or career; a young professional that wants to find the best educational/business continuation opportunity; or a more experienced professional who turns into a new area and wants to strengthen his/her expertise in the area.

- **author:** The ultimate goal of any type of authoring of learning resources is to support, improve and trigger learning, except for the fact that they don’t reflect the goals of a single learner, but those of a whole group of target learners. Authors are creators of Adaptive Learning Resources, but can have other tasks such as supporting synchronization, maintenance and usage in adaptive learning resources creation.

- **instructor:** An instructor is typically the only person directly communicating with the learner. This role can be considered as “a guide on the side” rather than “a sage on the stage”. Activities that can be carried out by instructors include:
  - Providing additional guidance to learners
  - Providing recommendations to learners
  - Assessment of learners’ work
  - Answering learners’ questions
  - Monitoring discussion
  - Promoting discussion

There are similarities between the author role and the instructor role related to authoring of learning materials. If it is for specific use (just one session or learner), then it is the instructor role. If it will be reused, it becomes authoring.

- **manager:** The training manager is responsible for efficient and effective training of the employees. This role is usually found in the literature under different names, for example as the learning manager role. Training management within a company can be also seen as a sub-discipline of human resource management. Therefore, training managers are sometimes referred to as human resource managers or human resource developers. In smaller companies this role is frequently covered by one of the general managers. As training managers are responsible for the whole company, line managers, project managers or group managers usually take some of their tasks at lower levels, in the departments or project groups. Group managers for example oversee specific subject areas and are responsible for the knowledge evolution in those fields.

- **administrator:** Administrators’ tasks are subdivided into user management, platform management and content management.
1. User managers have as tasks:
   a. Creation of a corporate user account
   b. Setting user rights
   c. Creating different types of users

2. Platform managers have as tasks:
   a. Setting new language for graphical user interface
   b. Managing the local settings
   c. Differentiating the visibility of the portal using themes
   d. Differentiating the portal main page
   e. Log management

3. Content managers have as tasks:
   a. Making the content invisible for all users or a set of users
   b. Learning modules management
   c. Defining resource types

The single author at the beginning of this section would have to unify the roles of PROLEARN author, instructor, manager and administrator.

In a more realistic setting, not only could these roles be taken by different persons, but there might be more than one person associated with each role. Therefore, in order to ensure collaboration and cooperation between the different roles and persons, both high-level and low-level semantics are vital. As Berners-Lee (2001) put it, the Semantic Web is “an extension of the current one, in which information is given well-defined meaning, better enabling computers and people to work in cooperation”.

From the point of view of adaptivity and Adaptive (Educational) Hypermedia, more roles can mean also a need for adaptation of each role separately.

Exporting between systems

The major case for semantic labelling is given by the answer of yes to the fourth question. Prior research and implementation of exporting and conversion between adaptive (educational) hypermedia authoring and adaptive (educational) hypermedia delivery systems (MOT to WHURLE; in Stewart et al., 2004, MOT to AHA!; in Stach et al., 2004 and Cristea et al., 2003, Interbook to AHA!; in De Bra et al., 2003b, AHA! to Claroline; in Arteaga et al., 2004) has shown that the most important step is the agreement on a common platform of semantics between the systems. This means that educational material with a given pedagogical structure created in one system can be delivered by another, while maintaining both the contents and the pedagogic semantics. On a peer-to-peer basis, such conversions can be done using local semantics without explicit connection to the Semantic Web standards. However, if these conversions have to be done on a larger scale, with arbitrary systems – such as considered for the PROLEARN portal – alignment to internationally accepted standards will become a necessity.

According to Schwartz, 2003, the Semantic Web “is meant to enable an environment in which independent, Internet-connected information systems can exchange knowledge and action specifications”. This means for the field of e-learning easy exchange and export of data and resources for e-learning.

If the answer is no, than, other, cheaper means will suffice – instead of the more time & energy consuming semantic annotation.

The Semantic Web Stack and Adaptive Hypermedia

The Semantic Web stack (Figure 1) has been proposed and gradually refined by Berners-Lee, 2003, and is supposed to guide us through the process of increasing level of semantics, as well as be always updated with the new corresponding web technologies.

The basis of semantics are resources, identified via their unique resource identifier (URI) or internationalized resource identifier (IRI). The next semantic layer is the XML, a set of syntax rules for “creating semantically rich markup languages in a particular domain” (Daconta et al., 2003) together with its namespaces (“a simple mechanism for creating globally unique names for the elements and attributes of the markup language”, to avoid vocabulary conflicts). On top of XML is the resource description framework, RDF, simply put, an XML
language to describe whole resources (as opposed to only parts of them, as with XML). RDF Schema is a language that enables the creation of RDF vocabularies; RDF Schema is based on an object-oriented approach.

Figure 1. The Semantic Web stack (Berners-Lee, 2003)

Semantics increases from the lower levels towards the top of the stack. Ontologies are constructed from structured vocabularies and their meanings, together with explicit, expressive and well-defined semantics. In particular, ontologies make knowledge reusable by featuring classes (general things), instances (particular things), relationships between those things, properties for those things (with their values), functions involving those things and constraints on and rules involving those things. Ontologies have their own spectrum of increasing semantics, as described in Figure 2 (Daconta et al., 2003).

Figure 2. The Ontology Spectrum (Daconta et al., 2003)
Taxonomies contain structured data, where the semantics of the relationship between a parent and a child node is not well specified (can be subclass of or part of). Thesauri are controlled vocabularies, with clearly defined equivalence, homographic (spelled the same way), hierarchical and associative relationships (e.g., WordNet http://www.cogsci.princeton.edu/~wn/). A conceptual model permits class-subclass hierarchies (as in UML). Logical local domain theories are directly interpretable semantically by the software, and represent the highest aspiration for ontologies.

As Dumbill, (2001) notes, speaking of an earlier version, “we should be careful not to restrict Semantic Web technologies to just those explicit layers in Berners-Lee's idealized diagram. There's obviously a difference between what is on the Web, and what is in the diagram (HTML is not mentioned, for instance)”. This is still true today, especially as the upper layers have not been nailed-down to a specific technology – although OWL (http://www.w3.org/2004/OWL/) is supposed to become the new WWW and Semantic Web-compatible ontology language (replacing DAML+OIL, McGuiness et al., 2002).

If we compare the latest Semantic Web stack with the Adaptive Hypermedia systems currently available, many AH systems don't make it even to the second level (XML), although all of them use higher level representations, such as Rules and sometimes a Logic framework. The main difference is not the representation level used, but the manner of its expression: first order logics (FOL) are often used, (loosely) coupled with If-Then rules or Condition-Action rules (e.g., Wu, 2002). However, the rules and the resources are often described together (De Bra et al., 2003a) or are mixed together with other functionalities of the delivery system. In the latter case, reuse is not possible.

None of the Adaptive Hypermedia systems actually goes up the scale in Figure 1 as far as Proof, and, as has been noted by Wu (2002), termination and confluence cannot be guaranteed for the general case in most AH systems. They usually require careful authoring by specialists aware of the possible pitfalls and loops.

However, we note in recent years more interest in XML and XML-based languages within the AH community, and systems such as AHA! (De Bra & Calvi, 1998), WHURLE (Moore et al., 2001) share this common base with the Semantic Web stack.

Adaptive Hypermedia attempts higher up the stack, with RDF and RDF schema representations have been done, e.g., in Personal Reader (Dolog et al., 2003), in GEAHS (Jacquiot et al., 2004), in Hera (Frasincar et al., 2003) and even OWL and RDF in DLRS (Maneewatthana et al., 2004).

LAOS: The Adaptive Hypermedia framework

The LAOS (Layered AHS Authoring-Model and Operators) model (Figure 3), introduced in Cristea & de Mooij (2003a), is a generalized model for generic, dynamic Adaptive Hypermedia (authoring), based on the AHAM model (Wu, 2002). The model consists of five layers:
- **domain model (DM)**: containing a collection of linked (learning or other) resources
- **goal and constraints model (GM)**: containing goal-related information, such as instructional and pedagogic information about the resources
- **user model (UM)**: containing user-related information, such as information about the learner
- **adaptation model (AM)**: containing the behaviour and dynamics, such as, a learning style related adaptive strategy (Cristea, 2004)
- **presentation model (PM)**: containing display and machine-related information, such as the foreground-background colour scheme for the course presentation.

LAOS was built on the idea of the separation of concerns, and therefore advocates the separation of information from the authoring perspective, as well as from the storage point of view. The main goals (or ‘credo’) of the LAOS model are as follows:
- **Flexibility**: seen as the semantically meaningful different combinations that can be generated by automatically populating the different layers of the LAOS model, based on previous ones. This automatic processing can only be done if the data in the original layers is semantically well-labelled. Semantically meaningful data and links can be then interpreted to generate new ones (Cristea, 2003).
- **Expressivity**: the semantics of the elements of the model should be machine understandable, for one thing, and also easy to grasp for humans (so that a course author, for instance, can understand what data and metadata he is creating).
- **Reusability**: to enable reuse of all aspects of the adaptive (educational) hypermedia.
Non-redundancy: to avoid creation of the same element of an AEH more than one time, in, for instance, a different context. This is essential, as most current AH systems would force you to define the same concept (such as a piece of courseware) twice, if it is used in a different context.

Cooperation: to allow the collaboration and cooperation of different authors, either synchronously, during the authoring process, or, more often, consecutively, during the building and refinement steps of, for instance, a courseware unit. Moreover, cooperation means that separation of concerns is applicable also for the authors, and task-specialized authors can be involved (such as domain specialists, adaptation specialists, pedagogy specialists, etc.).

Inter-operability: the framework should be generic enough, so that authoring of Adaptive Educational Hypermedia based on these principles could be easily converted into material for different AEH delivery platforms.
- **Standardization**: the framework should describe and extract patterns at the different levels of granularity, starting with the above five layers and detailing each layer separately; these patterns should be able to feedback into extant standards and provide information for enriching them according to the needs of adaptivity and pedagogy.

As can be seen, these goals are overlapping with the goals of the Semantic Web. Indeed, the Semantic Web requires the following:
- **Flexibility**: metadata for the Semantic Web, or structured data about data, should improve discovery of and access to such information (Signore, 2003, W3C), thus leading to flexible reuse and re-construction of the initial material in different contexts.
- **Expressivity**: the Semantic Web is giving meaning, in a manner understandable by machines, to the content of documents on the Web (WordfQ, Semantic Web definition)
- **Reusability**: the Semantic Web targets knowledge sharing (Signore, 2003, W3C)
- **Non-redundancy**: this is not a Semantic Web requirement as such; however, reuse on the Semantic Web implies that the content will not have to be regenerated, but just put in a different context.
- **Cooperation**: the Semantic Web targets collaborative development (Miller, 2003, W3C)
- **Inter-operability**: the Semantic Web aims at common metadata vocabularies (WordfQ, Semantic Web definition); and at “Leading the Web to its Full Potential...” “...by developing common protocols that promote its evolution and ensure its interoperability.” (Miller, 2003, W3C); interoperability should be both technical and semantic (Signore, 2003, W3C)
- **Standardization**: in order to have inter-operability, the Semantic Web is constantly developing new standards for web languages and technologies.

Another goal of the Semantic Web is to make the Web accessible to all by promoting technologies that take into account the vast differences in culture, languages, education, ability, material resources, and physical limitations of users on all continents (Signore, 2003, W3C). This goal is shared with the self-evident goal of Adaptive Hypermedia, which is catering for the different, personal needs of its users.

The layered design of LAOS, based on separation of concerns, also matches the request for modularity in the design principles for the web outlined by the Semantic Web (Signore, 2003, W3C).

It should be no wonder, therefore, that the result is Semantic Web compatible. In order to confirm this, in the following sections we shall express the LAOS model and its implementation, MOT, in standard Semantic Web languages, such as XML, XML Schema and RDF.

**LAOS for the Semantic Web**

Previously (Cristea & De Mooij, 2003a) we have expressed LAOS in terms of structure and functionality, and more recently, in terms of a list of basic definitions (Cristea, in press). Here we will only repeat the definitions that we convert directly, for the purpose of readability.

In order to verify the compatibility of LAOS with the Semantic Web, let us have a look at how we are able to express LAOS in terms of the Semantic Web languages. In the following, we are going to give some extracts of an XML Schema for LAOS.

As said previously, LAOS is built of five layers. Figure 4 shows an extract of the XML Schema of the LAOS model, listing these five layers.

Please note that the LAOS model can contain an unbounded (aka, unlimited) number of maps for each layer type. This means, for instance, that several *domain maps* corresponding to several books can be described within this model.

Similarly, different pedagogic goals will result in transforming the same domain map, for instance, into many different *goal and constraints maps*. Obviously, more than one user (or learner) can be defined with this model.

Note that, although individual *user maps* can also be defined with LAOS, the idea is to define either stereotypes, or groups of users, so that the same basic model can be reused. Of course, during the actual interaction of, for instance, a student, with the delivery system, this basic model will get updated and will generate several individual versions. This can happen, e.g., if all students are beginners, but some have been studying more than
others, and therefore accessed more pages or passed more tests. Their knowledge level will be accordingly updated by the delivery system and will be different for each user, although they all belong to the same basic category, beginner.

Furthermore, different presentation maps can be defined, giving the parameters, for instance, for a desktop presentation, or a palmtop presentation.

Finally, the material stored can be presented according to one or more adaptation strategies that can correspond to instructional strategies. For instance, an instructional strategy for the learning style ‘field-dependent’ (Stach et al., 2004) can be implemented by preferentially displaying the concepts at the same depth of the conceptual tree of either a goal and constraints map or domain map.

Also note that the XML schema elements of the LAOS model in Figure 4, such as ‘domainMap’, ‘goalAndConstraintsMap’, ‘userMap’, ‘presentationMap’ and ‘adaptationStrategy’ are defined as being of a type of the same name, which still has to be defined (e.g., element named ‘domainMap’ is of type ‘domainMap’ in a namespace ‘mns’).

In Cristea, (in press) we defined a domain map as follows:

A domain map DM of the AH system is determined by the tuple \( <C, L, Att> \); where \( C \) a set of concepts; \( L \) a set of links and \( Att \) a set of DM attributes.

Let’s see how the respective ‘domainMap’ type will look in XML Schema. Figure 5 shows the definition of the XML schema type ‘domainMap’, as composed of two elements, concept map information and a root element of the hierarchy of concepts. This hierarchy of concepts is further detailed in Figure 6, where the type ‘complexDomainConcept’ is detailed as being composed of a current concept, and an unbounded list of sub-concepts. The hierarchy corresponds to (an instance of) the set of links \( L \) in our former definition. There are different links that can appear in a domain map, beside the hierarchic ones, but we are not going into details in the current paper. The concepts in the hierarchy correspond to the set of concepts, \( C \). The concept map information, defined as the type ‘conceptMapInfo’ in Figure 7 lists the attributes that describe the concept map. These correspond to \( Att \), the set of domain model attributes.

Figure 4. LAOS XML Schema extract: the LAOS model

Figure 5. LAOS XML Schema extract: the domain map
In Cristea, (in press) we defined a domain concept as follows:

A **domain concept** $c \in \text{DM}$ is defined by the tuple $< A, C >$; where $A \neq \emptyset$ is a set of domain map attributes; $C$ a set of domain map sub-concepts; DM the domain map instance the concept belongs to.

Figure 6 defines, as said, the 'complexDomainConcept' consisting of a main part, the 'domainConcept', and an unbounded set of sub-concepts; the type 'domainConcept' consists of some general concept information (not given here due to lack of space) and an unbounded set of extra attributes (element 'extraAttribute').

```
<xsd:complexType name="complexDomainConcept">
  <xsd:sequence>
    <xsd:element name="domainConcept" type="mns:domainConcept" minOccurs="1" maxOccurs="1"/>
    <!-- list of sub-concepts -->
    <xsd:element name="subConcept" type="mns:complexDomainConcept" minOccurs="0" maxOccurs="unbounded"/>
  </xsd:sequence>
</xsd:complexType>
```

**Figure 6. LAOS XML Schema extract: the domain concept**

```
<xsd:complexType name="conceptMapInfo">
  <xsd:sequence>
    <xsd:element name="description" type="xsd:string" minOccurs="0" maxOccurs="1"/>
    <xsd:element name="owner" type="mns:author" minOccurs="1" maxOccurs="1"/>
  </xsd:sequence>
  <xsd:attribute name="id" type="xsd:nonNegativeInteger" use="required"/>
  <xsd:attribute name="creationDate" type="xsd:date" use="required"/>
  <xsd:attribute name="modificationDate" type="xsd:date"/>
</xsd:complexType>
```

**Figure 7. LAOS XML Schema extract: the concept map information**

To see how an actual instance of a domain map will look when we use the XML Schema defined above, see Figure 8. The figure shows an actual instance with completed attributes, such as the attribute ‘introduction’, and ‘text’ of a concept on “Neural Networks”. The content displayed is kept short for visibility.

To examine now the other elements in Figure 4, we look at the definition of a goal and constraints map (Cristea, in press):

**A goal and constraints map** GM of the AH system is a tuple $< G, GL, GAtt >$; $G$ represents a set of goal and constraints concepts; $GL$ a set of goal and constraints links and $GAtt$ is a set of goal and constraints attributes.

The XML Schema definition of ‘goalAndConstraintsMap’ is similar to that of the ‘domainMap’ in Figure 5, and the general information on it is identical to that in Figure 7, and will therefore not be discussed any further.

With this the mapping from the original definition to the XML Schema is accomplished. Instead, Figure 9 shows the main difference that appears.

In Cristea (in press), we defined:
A goal and constraints concept $g$ is defined by the tuple $\langle GA, G, DM, c, a \rangle$; $GA \neq \emptyset$ is a set of attributes; $G$ a set of sub-concepts; $DM, c \in C$ is the ancestor domain map concept and $DM, c, a \in A$ is an attribute of that concept.

with the following restriction:

**Constraint.** Each goal and constraints concept $g$ must be involved in at least one special link $gl$, called prerequisite link (link to ancestor concept). Exception: root concept.

**Figure 8.** LAOS XML Instance extract: an example domain concept map

Figure 9 defines the type 'goalAndConstraintsConcept', with, as is expected, concept information as in Figure 7 and extra attributes, corresponding to the set of attributes in the 'goal and constraints concept' definition above. The constraint of the prerequisite link is given by the concept hierarchy, which is not repeated, as it is similar to that of domain concepts. Moreover, the 'order' element in the XML schema in Figure 9 can decide the order in which the concepts can appear.

**Figure 9.** LAOS XML Schema extract: the goal and constraints map

An example of a partially filled-in goal and constraints concept map, with hierarchy and attributes, is displayed in Figure 10. For readability, header, schema location and namespace information are omitted.

The figure shows a goal and constraints concept map created based on the domain map with concepts such as in Figure 8. It contains one root concept with the title "Neural Networks Intro Text", corresponding to the domain concept with Id=3 (as in Figure 8), and two sub-concepts: "Biological Neuron Intro Text" and "Artificial Neuron Intro Text" (based on domain concept with Id=5 and Id=9, respectively).
The presentation map is very similar in structure, with the only difference that the attributes in it reflect machine characteristics; hence this will not be discussed any further.

Figure 11 shows the XML schema extract of the user map. Here we are using an extended definition based on the one in Cristea (in press), as follows:

A user concept \( u \) is defined by the tuple \( \langle AU, U, GM_i(g.(a))/DM_i(c.(a)) \rangle; AU \neq \emptyset \) is a set of user model attributes; \( U \) a set of UM sub-concepts; \( GM_i(g.(a))/DM_i(c.(a)) \in G/C \) is the ancestor goal and constraints map (or domain map) (concept or concept attribute).

This definition describes in a very compact form the fact that user model attributes can be layered over different types of maps – such as domain maps or concept maps. Moreover, it expresses the fact that user model attributes can be overlaid within these maps at different levels - such as at the level of the whole map, or at the level of a concept, or finally, at the level of an attribute.

To explain why we need all these different overlay levels, let’s look at a simple example. We have the goal and constraints map in Figure 10, and we try to express the knowledge of the user regarding this map. We can say the user’s global knowledge is 70%, or we can detail it and say that the knowledge corresponding to goal and constraints concept with id= “14” is 70%, that of id= “32” is 60% and that of id= “22” is 80%. In a domain concept map such as the one depicted in Figure 8, we can go below the level of the concept with id= “3” and talk about the knowledge corresponding to the attribute “text”, or the attribute “introduction”, etc. Therefore, in order to allow user map attributes such as ‘knowledge’ to be refined and attributed to the different parts of the content, we need to define different levels of overlay.

The XML Schema in Figure 11 implements this idea, by allowing three layers of overlay for the domain model. If the goal and constraints map is not adding extra attributes (as defined up to now in the XML Schema extracts),
then an overlay at the map level is enough. This is due to the fact that the goal and constraints concepts correspond to domain map concept attributes.

The actual definition of these overlay types is not discussed, due to lack of space.

The last, but quite different type definition refers to the adaptation strategy. Adaptation strategies represent the only dynamic part of the LAOS model. They are the ones instructing the delivery engine about how to handle the static data generated by the other layers. Figure 12 shows the XML Schema for the LAOS adaptation strategies. Beside having the ‘conceptMapInfo’, just like all the other concept maps previously shown, an adaptation strategy looks very much like a program, listed as the element ‘strategyText’ in Figures 12 & 13. However, the programming language is restricted to the adaptation language as defined in (Cristea & Calvi, 2003). Other elements of the strategy are its ‘inputVariables’, such which concept maps are used; ‘usedLanguageConstructs’, with the sub-list of adaptation language constructs used and ‘usedProcedures’, the author-defined extensions to the adaptation language.

Figure 12. LAOS XML Schema extract: the adaptation strategy

Figure 13 shows a short instance populating the schema in Figure 12. The strategy only determines that if the user is a beginner, he should see the lesson ‘Neural Networks for beginners’. Other, more complex strategy implementations have been discussed elsewhere (Cristea, 2004) and are not further detailed here.
MOT: The adaptive (educational) hypermedia authoring system

MOT (My Online Teacher) is an Adaptive Educational Hypermedia authoring system developed based on the LAOS framework. At the time of the writing, MOT implements:

- the domain model, as a conceptual domain model for courses (Cristea & De Mooij, 2003b),
- the goal and constraints model, as a lesson model, (Cristea & De Mooij, 2003b)
- the user model, as a first version of a hybrid model (in idea similar to Zakaria & Brailsford, 2002) featuring both stereotypes and overlay user model, as well as personal information, interests, etc.
- the adaptation model, in the form of an (instructional) adaptive strategy (Cristea, 2004) creation tool, based on an adaptive language (Cristea & Calvi, 2003) that uses as an intermediate representation level of LAG (Layers of Adaptive Granulation) grammar (Cristea & Verschoor, 2004)
- the presentation model is currently being implemented, in the form of a hybrid model, similar to the user model.

MOT conforms to the LAOS principles, using a concept-oriented approach. This means that the information about a course, for instance, is stored in MOT in the form of linked domain concepts, expressed by their attributes, as we have previously seen in the LAOS description.

MOT features some recommended, standard attributes, some of which have been shown in Figure 8: title, keywords, pattern, introduction, text, explanation, conclusion and exercise. The combination of these given attributes and the keywords used to describe concepts can lead to automatic discovery of relatedness links “and hence to improve the consistency and breadth of linking of WWW documents at retrieval time (as readers browse the documents) and authoring time (as authors create the documents)”, as in COHSE (Carr et al., 2001).

As ontological reasoning is based on rich semantic annotation & labelling (Schwarz, 2003), the labelling in MOT, together with the layered structure inherited from LAOS, creates a basis for ontological processing. Therefore, some reasoning within MOT is possible. This is reflected at the level of the adaptation model, where adaptation strategies can be designed not only at instance, specific level (such as in writing a rule about the piece of material called “Neural Networks for beginners”), but also at a generic level (such as a rule specifying to show all material labelled “introduction” in the current lesson).

MOT for the Semantic Web

MOT is written in Perl and its data structures are stored in MySQL, in order to be both flexible and easy to export. As has been shown previously, this format allows MOT to interface with different delivery systems, such as AHA! (Stach et al., 2004) and WHURLE (Stewart et al., 2004).

In the following, we will look at and comment upon an exercise to express MOT in the Semantic Web language RDF.

Figure 14 shows extracts of the RDF Schema of MOT and Figure 15 shows an RDF instance of MOT, for the Domain Map and the Goal and Constraints Map. The figures also reflect the connection between the Domain Map and the Goal and Constraints Map, conform with the LAOS goal of non-redundancy: the information from the Domain Map is filtered and restructured in the Goal and Constraints Map in order to be more appropriate for
the actual presentation, but is not copied, just referred to (via pointers). For both figures, the left-hand side represents the Domain Model, and the right-hand side the Goal and Constraints Model. The upper side is the author information. Let’s look first at Figure 14.

**Figure 14.** RDF Schema of two MOT layers (Cristea & De Mooij, 2003a).

A MOT domain ‘concept map’ couples the ‘name’ of a ‘designer’ to a hierarchy of concepts. It contains a pointer to the root of this concept hierarchy. The structure of this hierarchy is stored in several ‘concept hierarchy’ objects, as follows.

A MOT domain concept contains one or more sub-concepts, which are concepts in their turn, hence inducing a hierarchic (tree) structure of concepts (‘superconcept_is’, ‘subconcept_is’). The hierarchical structure of concepts is implemented by means of a separate ‘concept-hierarchy’ entity, relating a super-concept to one or more sub-concepts.

Each domain concept ‘contains’ domain attributes. These attributes hold pieces of information about the concept they belong to. There are several kinds of attributes possible, corresponding to the different attribute instances in the diagram. For example, a concept can have a ‘title’-attribute, a ‘description’-attribute or an ‘example’-attribute.

Domain attributes can be related to each other. Such a relatedness link (as previously discussed), is characterized by a ‘label’ and a ‘weight’, and indicates that their contents treat similar topics. A relatedness-relation is also given a type, indicating by which attribute(s) the concepts are related. This type is one of the possible attribute types (for example ‘title’, if the concepts are related by their titles).

In MOT, the goal and constraints map is expressed as a ‘lesson’ map. A lesson couples the ‘name’ of a ‘designer’ to a hierarchy of sub-lessons. It contains a pointer to the root of the sub-lesson hierarchy, which consists of sub-lessons which are related by means of ‘lesson hierarchy’ objects, comparable to the ‘concept hierarchy’ objects in the concept domain.

Sub-lessons within a lesson can be OR-connected (therefore becoming lesson alternatives, from which the appropriate one will be selected according to user map variable settings) or AND-connected (meaning that a student has to study all sub-lessons, regardless). To facilitate this, a lesson contains a lesson attribute, which in its turn contains a holder for OR-connected sub-lessons or a holder for AND-connected sub-lessons. The holder contains the actual sub-lessons in a specified order (as previously mentioned).
A lesson attribute contains, besides the sub-lesson holders, one or more pointers to domain concept attributes. This is the link with the concept domain. The idea is that the lesson puts pieces of information that are stored in the concept attributes together in a suitable way for presentation to a student. A sub-lesson which has no sub-lessons (e.g. is a leaf in the sub-lesson hierarchy) corresponds to a (one) concept attribute.

Figure 15 shows and example RDF instance of MOT, using the RDF Schema in Figure 14.

For the domain map side (left hand side of Figure 15), we can see in the figure how concept r11 is the root of the concept map r2 owned by the designer r1. The concept r4, belonging to the same concept map is called “Discrete Neuron Perceptrons” and is a direct child of r11. Attribute r9 called “Keywords” is contained in concept r4 and contains the keyword list “perceptron; one-layer; multi-layer; weight; linear separability; perceptron convergence; boolean functions; region classifications in multidimensional space”. Moreover, concept r4 is related to concept r12 via the attribute “Keywords” in a proportion of 24%.

For the goal and constraints map side (right hand side of Figure 15), the figure shows the previously mentioned attribute r9 expressing the “Keywords” of concept r4 as being assembled in sub-lesson r5, which is also the root of the lesson model. Lesson r5 also contains sub-lesson r10 in an OR connector (connection=“0”) with the weight 30%, the priority order “2” and the label “detailing keywords”.

**Conclusion**

We have shown in this paper what the benefits can be for e-learning for joining the Semantic Web, as well as expanded on the possible synergistic effects of merging Adaptive (Educational) Hypermedia with the Semantic Web. We have shown that ideologically, these two fields share many commonalities, however, in practice only part of the Web Technologies are (successfully) being adopted.

Moreover, we have shown an exercise in integration by using Semantic Web languages to express LAOS, an Adaptive Hypermedia (authoring) framework and MOT, an authoring system for Adaptive Educational Hypermedia implemented based on the LAOS credo.
Semantic Web enthusiasts often encourage everybody to implement the new Web technologies, in order to bring the great promise of a 'web-of-meaning', step-by-step, iteration-by-iteration, closer to fruition. However, critics complain about the unripe technologies, about the lack of support, and about the problems with keeping the systems up-to-date with the ever newer versions of the standards. Moreover, critics mainly complain that there is too much extra work in addition to creation of resources (such as, the extra annotations of the created resources; the building of ontologies to match the resources; and finally, the merging of ontologies – a NP complete problem) and the return on this investment still lingers somewhere in the future.

However, given the amount of interest, effort and money put into the Semantic Web development, there seems to be less and less doubt that, eventually, it will deliver. Therefore, the question appears to be whether to adopt the standards early, fighting with all the associated problems but also having an influence on the solutions, or to join in when the technology and standards are ripe.

Standardization is something to be sought for, if interoperability is an issue. For e-learning there are other useful standards for specifications on the learning resources, such as the "Learning Objects Metadata Standard" (LOM) (http://ltsc.ieee.org/wg12/) by the Learning Technology Standards Committee (LTSC) of the IEEE, established as an extension of Dublin Core. A related standard is the SCORM, the Sharable Content Object Reference Model (http://www.adlnet.org/). Both attempt to foster the creation of reusable learning objects, in a similar manner to that of the Semantic Web. Another attempt is the effort towards standardization of the user (learner) information to be maintained by a (learning) system. Two standards of importance have emerged out of this effort, PAPI for Learner (Public and Private Information for Learner) (http://ltsc.ieee.org/wg2/ and http://edutool.com/papi/) and IMS LIP (Learning Information Package) (http://www.imsglobal.org/profiles/index.cfm). These standards define several categories for information about a user (learner).

For education and e-learning this means they must ask themselves the question if the extra-effort towards Semantic Web standards is affordable and feasible. The latter question we have explored with the example of an Adaptive Educational Hypermedia framework conversion into Semantic Web language. This exercise shows that, if the principles are aligned, the actual conversion is feasible, even if not always easy. The affordability is something to be decided on a case-by-case basis.

In this way, we have explored in this paper not only what the Semantic Web can do for Adaptive Educational Hypermedia, as declared in the title, but also how this conversion from Adaptive Hypermedia to the Semantic Web might be achieved.

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