

# ADAPTATION ENGINE CONSTRUCTION BASED ON FORMAL RULES

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**Keywords:** AHS, e-Learning, User model adaptation, Formal rules.

**Abstract:** With last achievements in research and practical development of adaptive hypermedia systems, they start being more and more promising for e-learning adaptable to personal learner needs, style and performance. Every year there are constructed new technology enhanced platforms with adaptation engines controlling content management and delivery. A great problem with adaptation engine designs is that few of them facilitate a flexible and manageable control over adaptation processes. This paper is focussed exactly on problems with effective conceptual construction of adaptation engine, by means of formalization of our adaptation model for hypermedia learning courseware management and delivery. The article describes in brief a formal definition of both adaptive rules and adaptive process supporting the model. The approach proposed for adaptive engine's construction follows a rule-driven approach and is consistent with that formalization. The implementation of the platform is under development and relies strongly on conceptual separation of adaptive rules from business logic. This guarantees an ability for editing adaptive rules at run time and, thus, to manage the adaptation process in a very flexible way.

## 1 INTRODUCTION

In last decade, many software platforms for technology-enhanced learning have been developed. However, only few of them offer adaptation of e-learning process according needs and expectations of individual learners. Adaptive platforms such as adaptive hypermedia system (AHS) are entirely oriented to individual user's goals, preferences and knowledge (Brusilovsky P., 1994). AHS use various decision mechanisms and methods of assuring adaptation and of provisioning educational content in a way most satisfying student needs (Dagger, D., Wade, V. & Conlan, O., 2005). Some AHS achieve it using widespread techniques such as adaptive navigation, structural adaptation, adaptive presentation and content selection. These techniques could be used for implementation of static adaptation or of dynamic one - driven by an engine controlling the adaptation. Other of them introduce additional level of system self adaptability based on the idea that different forms of learner model can be used to adapt content and links of hypermedia pages to given user. All of AHS have built-in engines controlling adaptation by choosing what adaptive technique to apply and managing the entire process.

The present paper discusses an approach construction of adaptive engine by defining and executing symbolic rules. Symbolic rules tend to be most suitable for implementing our conceptual model of an adaptive hypermedia system. Using symbolic rules for construction of AHS promises to be very universal thanks to abilities for run time redefinition and control and, also, possible system redevelopment for supporting other adaptation models. After providing a comparison of most prominent adaptation methods, the paper goes to a brief description of our triangular conceptual model of AHS. The functionality of the adaptation engine is formalised and two ways for its construction are discussed: one by using Drools rule engine (Proctor, M. et al., 2008) and another one by rule descriptions in SWRL. Both these ways allow flexible software construction of the engine allowing easy expandability and adaptation control at run time.

## 2 COMPARISON OF ADAPTATION METHODS

There are various well-established ways for ensuring adaptation. Following them, the adaptation engine

Table 1: Comparison between methods for construction of adaptation engine.

<i>Methods</i> <i>Criteria</i>	<i>Symbolic rules</i>	<i>CBR</i>	<i>IMS LD</i>
<i>independence</i>	YES (adaptation rules are defined independently)	NO (it depends on the cases and not only on adaptation rules)	YES (by a XML meta-language allowing scenarios to be separated from learning materials)
<i>reuse / repurposing</i>	YES (adaptation rules are used for each learning material under certain conditions)	NO (a consequence of the independence)	YES (various pedagogical strategies describing by XML files can be applying in different learning materials)
<i>implementation complexity</i>	NO	YES	YES
<i>level of adaptation</i>	high (depending on defined rules, it can allow possibility for self adaptation)	high (it allows possibility for self adaptation)	average (its adaptation is based on pre-defined methods, conditions, calculations, etc.)
<i>interoperability</i>	YES (for rules' description, there can be used XML based languages such as RuleML, SWRL or first-order logic predicates)	NO (there is not a standardised way for CBR description)	YES (it is a specification and can be used between systems supporting it)

can be constructed by means of methods as follows:

- symbolic rules – this is one of the most illustrative methods for presenting adaptation. The adaptation is described by setting rules of type <if-then>. The rules set conditions and actions to be implemented when these conditions are observed.
- case-based reasoning (CBR) (Zongmin Ma (Ed), 2006) – an approach that stores a set of past situations with their solutions and, in similar or same cases, uses them or a similar solution. There are four phases of implementation: retrieve, reuse, revise and retain. Usually this approach is used to assess learner knowledge and perform instructional tasks (Guin-Duclosson, N. et al., 2002).
- IMS Learning Design (IMS LD) (Berlanga, A. et al., 2006) – this is a meta-language for learning scenarios description maintained by IMS Global Learning Consortium. Adaptation can be provided by defining conditions for the presentation of learning content and sequencing of learning activities.

Here we present a comparison between these three ways for construction of the adaptation engine as summarised in table 1. The selection criteria are based on our main requirements to realization of adaptive engine (namely, it should be flexible and manageable) and its easy implementation. The goal of this comparison consists in selection of the most appropriated method among them. Based on the

results obtained from table 1 and in accordance with our aims defined in the introduction, we choose to use symbolic rules for defining of adaptation mechanism.

### 3 AHS CONCEPTUAL MODEL

The AHS model described in details in (Vassileva D. & Bontchev B., 2006) follows a metadata-driven approach, explicitly separating narrative storyboard from the content and adaptation engine (AE). Fig. 1 represents the triangular structure of our model which refines the AHAM reference model (De Bra P., Houben G.-J. & Wu H., 1999) by dividing in three each one of the learner's (or, generally speaking – user's), domain, and adaptation models. At first level, the model is based on a precise separation between learner, content and adaptation model, while at second level each of these sub-model is divided into three others sub-models (Vassileva D. & Bontchev., B., 2006).

Fig. 1 represents the triangular structure of the model. Unlike other approaches, in the learner model we separate goals and preferences from shown knowledge and performance, as the first sub-model is static while the second one is rather dynamic and takes a part in the event-driven storyboard monitoring. The model of learning style (learner characters such as activist, pragmatist, theorist, or reflector) is detached as another learner sub-model and can be used for choosing contents for

given learning style. While the learning style can be determined in the very beginning of the learning explicitly by the learner or by appropriate pre-tests, other tests should be exercised during the e-learning process in order to assess prior or gained knowledge and performance results of each individual student.

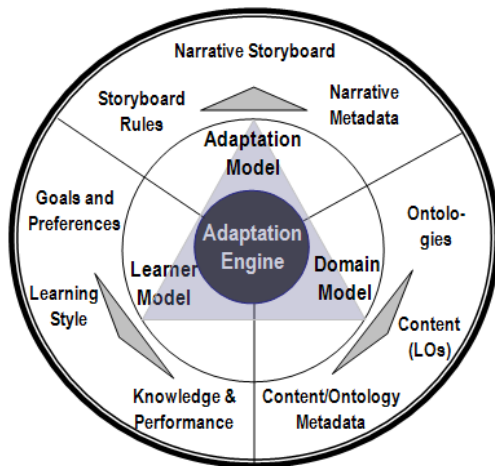


Figure 1: Structure of the triangular conceptual model.

The domain model is composed of content itself (granulized in learning objects (LOs) according to the SCORM standard) (López, M. et al., 2006), LO's metadata (LOM) and LO's content assets (images, text, tables, etc.) forming a logical taxonomy for the knowledge domain built upon domain ontology during the course composition process by the course author. The content LOs are placed by the instructor on course pages, while pages represent nodes within course storyboard graph. Content pages delivery is controlled by the adaptation engine (AE) for choosing most appropriate content for presenting it to the user with given learning model. Instead of choosing dynamically a page (i.e. node of the storyboard graph) with its content, we propose choice of best working path within the graph for specific learner with given learning style on one hand, and shown prior knowledge and performance on the other.

The adaptation model (AM) captures the semantics of the pedagogical strategy employed by a course and describes the selection logic and delivery of learning activities/concepts. AM includes a narrative storyboard sub-model supporting course storyboard graphs, which may differ for different learning styles. It consists of control points (CP) and work paths (WP). Moreover, AM should provide a schema of storyboard rules used for controlling the e-learning process. Storyboard rules determine sequencing of the course pages upon inputs from

learner sub-models. The narrative metadata sub-model sets such rules for passing a CP (e.g., as threshold level of assessment performance at that CP) or for returning back to the previous CP.

The core of our model is the adaptation engine (AE) which is responsible for generating the actual adaptation outcomes by manipulating link anchors or fragments of the pages' content before sending the adapted pages to a browser. The AE uses an event-driven mechanism for controlling the storyboard execution based on the storyboard rules applied to the inputs from the learner model. AE selects the best storyboard WP within the graph by evaluating weight coefficient of the pages within the WP for the given learner style (Vassileva, D., Bontchev, B. & Grigorov, S., 2008).

AE is responsible for performing all necessary adaptation mechanism for content delivery to a specific learner. This includes content selection, content hiding, link annotation, link hiding, etc. When learner starts a new course, adaptive engine finds the best path for him/her in the course graph. The best path is that one with the highest weighed score. For a particular user, the best path is calculated by a sum of multiplications between page parameters values and weights of their correspondent learner's characters.

#### 4 FORMAL SPECIFICATION OF THE CONCEPTUAL MODEL

For description of formal model, there can be used Object Constraint Language (Richters, M. & Gogolla, M., 1998) like in the Munich Reference Model (Koch, N. & Wirsing, M., 2002), descriptive language for specification like in GAHM (Ohene-Djan, J. et al., 2003) or predicate logic like in the Dexter Hypertext Reference Model (Halasz, F. & Schwartz, M., 1994). In order to assure an easy construction of adaptation rules, we preferred to use predicate logic for formal model description.

Predicate logic is extension of propositional logic with separate symbols for predicates, subjects and quantifiers. Its formulas contain variables which can be quantified enabling clearer adaptive process understanding and more precise adaptive rules description. By means of predicates, we formalise the learner model (e.g., by a predicate we show the level of belonging of a user to given learning style), the domain model, the adaptation model and, finally, the adaptation engine. Once we have defined the predicates describing main functionalities of the

triangular model we can begin giving adaptive rules. They can be presented by defining relationships between the predicates. The adaptive rules can be divided into three main groups in accordance to their purpose:

- starting rules - describe learner knowledge and initial conditions for starting a new course, for example if the user knows all learning objects contained in a subject, then she/he knows that subject:
 
$$(1) \forall user_i \exists subject_j (\forall lo_k lo\_4\_subject(subject_j, lo_k) \wedge user\_knows\_learning\_object(user_i, lo_k)) \rightarrow user\_knows\_subject(user_i, subject_j)$$
- pass-through graph rules – consist of rules for the graph crawling, e.g. if the learner does not pass the test at a control point, she/he continues backward:
 
$$(2) \exists k (user\_performance(user_i, subject_j, control\_point_k, fail)) \rightarrow next\_cp\_path(user_i, subject_j, control\_point_{k-1})$$
- rules updating learner model – related to learner knowledge and performance, such as the following: if the learner passes all control point's tests for particular subject then the learner knows it:
 
$$(3) \forall k (user\_performance(user_i, subject_j, control\_point_k, pass)) \rightarrow user\_knows\_subject(user_i, subject_j)$$

## 5 ADAPTATION ENGINE

In this chapter, there is presented in brief a proposal for construction of adaptation engine by means of symbolic rules. For realizing such a goal, the most suitable means to be used are a rule description language such as SWRL (Mei, J. & Boley, H., 2006) and its execution engine, or a rule execution platform such as Drools (Proctor, M. et al., 2008) and Jess (Hill, E. J. F., 2006). We have chosen to present our rules both through Drools and SWRL. Motives to select exactly them are that on the one hand, for Drools and SWRL, there are available very good and convenient graphical editors and tools for presentation, editing and reviewing rules such as Protégé for SWRL and RuleFlow for Drools. On the other hand, SWRL aims to be the standard rule language of the Semantic Web, which will allow interoperability between different rule engines. Also, Drools can reduce complexity of components that implement the business rules logic in Java

applications, and it is easy to maintain or extend the business logic by declarative programming.

### 5.1 Drools Overview

The Drools is an open source rules engine Java implementation expressing business logic rules in a declarative way. The Drools architecture is based on three main components: production memory that stores the rules, working memory that stores the facts and the inference engine. The rules can be writing using a non-XML native language – Drools Rule Language (DRL), a XML native language as an alternative of DRL which allows capturing and managing rules as XML data and in a spreadsheet format (supported formats are Excel and CSV).

Drools development platform comes in two flavours: as an Eclipse plug-in Drools IDE and as Web application Drools BRMS. The Drools IDE provides developers with an environment to edit and test rules in various formats, and integrate it deeply with their applications from within Eclipse. The IDE has a textual/graphical rule editor, a RuleFlow graphical editor, a domain specific language editor. Other advantages of the Drools are:

- it separates your application from conditions which control the flow:
  - rules are stored in separate files
  - changing rules does not require to recompile or redeploy the application
  - putting all rules into one place makes it easier to control the application flow
- problems are not solved using a complicated algorithm, but via rules, which are easier to read and understand than code
- Drools is supported by an active community of Java developers

### 5.2 Drools Rules

The structure of a Drools' rule includes one or more attributes providing a declarative way to influence the behavior of the rule, one or more conditions (in *when* section), and a list of actions (in *then* section). For example, the rule (2) given within the previous chapter can be written as Drools' rule like this:

```
rule "Fail the test in control point on level k"
when
    UserPerformance(user_i:user_id,
                    subject_j:subject_id,
                    control_point_k:control_point_id,
                    value=="fail")
then
```



```

eval(NextCpPath(user_i, subject_j,
               control_point_k-1));
end;

```

where in the section *when* is described the left hand side of formulas (2) and in the section *then* is described right hand side of (2). Thereby, all the formulas formally defined by predicates should be converted to DRL rules. The resulted DRL rules are used by the inference engine together with the facts (e.g., data about both the learning model and the adaptation model).

### 5.3 SWRL Overview

SWRL is intended to be the rule language of the Semantic Web. SWRL is based on OWL and all rules are expressed in terms of OWL concepts. A SWRL file is an OWL ontology, whose axioms are extended with rule axioms. It thus extends the set of OWL axioms to include Horn-like rules and enables Horn-like rules to be combined with an OWL knowledge base. The SWRL rules can be described through Abstract Syntax, XML Concrete Syntax and RDF Concrete Syntax. SWRL allows users to write Hornlike rules expressed in terms of OWL concepts to reason about OWL individuals. The rules can be used to infer new knowledge from existing OWL knowledge bases.

The SWRL Specification does not impose restrictions on how reasoning should be performed with SWRL rules. Thus, investigators are free to use a variety of rule engines to reason with the SWRL rules stored in an OWL knowledge base.

### 5.4 SWRL Rules

In common with many other rule languages, SWRL rules are written as antecedent-consequent pairs. In SWRL terminology, the antecedent is referred to as the rule body (*rule\_evl:body* tag) and the consequent is referred to as the head (*ruleml:head* tag). The head and body consist of a conjunction of one or more atoms. At present, SWRL does not support more complex logical combinations of atoms. SWRL also supports literals, built-in predicates, which greatly expand its expressive power. For example our rule (3) can be written in SWRL XML Concrete Syntax like that:

```

<ruleml:imp>
  <ruleml:body>
    <swrlx:individualPropertyAtom
      swrlx:property="user_performance">
      <ruleml:var type="xsd:int">

```

```

        user_i</ruleml:var>
      <ruleml:var type="xsd:int">
        subject_j</ruleml:var>
      <ruleml:var type="xsd:int">
        control_point_k</ruleml:var>
      <ruleml:var type="xsd:string">
        result</ruleml:var>
      <owlx:Individual owlx:name="#pass"/>
    </swrlx:individualPropertyAtom>
  </ruleml:body>
  <ruleml:head>
    <swrlx:individualPropertyAtom
      swrlx:property="user_knows_subject">
      <ruleml:var type="xsd:int">
        user_i</ruleml:var>
      <ruleml:var type="xsd:int">
        subject_j</ruleml:var>
    </swrlx:individualPropertyAtom>
  </ruleml:head>
</ruleml:imp>

```

### 5.5 Comparison between Drools and Jess Rule Engines

Now, we will do a comparison between the two rules engines selected above (Drools and Jess) for construction of our adaptive engine. For the purpose of comparison we define several criteria (table 2). In the table, they are described rule engines properties for each defined criterion. As we see, Drools outweighs Jess especially because of availability of very good means for rule creating and editing and of its maturity and open solution.

Table 2: Comparison between Drools and Jess.

Rule engine	Drools	Jess
<b>Criteria</b>		
<b>Interoperability</b>	no	no
<b>Rules tools</b>	yes (special IDE, Rule-Flow)	no
<b>JSR94 support</b>	yes	yes
<b>Maturity level</b>	++++	++
<b>Availability</b>	open source	commercial with academic license
<b>Mode of working</b>	run from JVM	shell or batch, plugin in Protégé
<b>Classes and instances</b>	Java objects	CLIPS file

## 6 CONCLUSIONS

Future years will prove the potential and great promise of adaptive hypermedia proposals being nowadays under discussion. The present paper

introduced a new conceptual approach for self adaptive hypermedia applications using triangular conceptual model. The proposed model offers many advantages but the main one consists in assuring strong independence of any of the building models and, at the same time, in facilitating a flexible adaptation of content delivery. The adaptation makes use of adaptive presentation, navigation support and content selection; it is not locked to any given learner model. In order to be able to describe polymorphic learner profiles, we use concepts of given domain such as characteristics of the learning style, psychology characters, etc.

The adaptive process for e-learning content delivery was formalized through usage of predicates and relationships between them. On the base of such predicates, there were built formal rules controlling the adaptation process and executed by the adaptation engine. For describing the rules, two approaches have been considered – Drools Rule Language and SWRL. Both the approaches are supported by rule engines which executes rules described in correspondent language. Thanks to the fact they both support rules defined by first order logic predicates, we conclude they are suitable for constructing an adaptation engine supporting the conceptual model. Based on this comparison showing the weaknesses and advantages of the rule engines, we may choose Drools for the ongoing implementation of the adaptation engine. The choice of Drools is strongly influenced by the facts it provides advanced rule management tools, detailed documentation, and open source license. The adaptation engine is going to be integrated and tested within a adaptive e-learning platform providing an authoring tool for construction of learning courseware and an instructor tool (Vassileva, D., Bontchev, B. & Grigorov, S., 2008) for structuring the narrative storyboards and planning the instructional design.

## ACKNOWLEDGEMENTS

This work is partially supported by the SISTER project funded by the European Commission in FP7-SP4 Capacities via agreement no.: 205030.

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