

Poster Presentation  
Third Workshop on Adaptive Hypertext and Hypermedia  
at the 8<sup>th</sup> International Conference on User Modeling,  
Sonthofen, Germany, July 13-17, 2001

## **Software Engineering for Adaptive Hypermedia Applications?**

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### **Development of Adaptive Hypermedia Applications**

The Programming and Software Engineering Research Group of the Institute of Computer Science of the Ludwig-Maximilians University of Munich is focusing on software engineering for hypermedia and Web applications in general and, particularly, for adaptive applications. One main goal of the software engineering discipline is to find techniques that support the development process of software applications. Our goal is to find, between others, appropriate analysis and design techniques that support development and authoring of adaptive hypermedia and Web applications.

General object-oriented software engineering approaches, such as the Unified Process (Jacobson, Booch & Rumbaugh, 1999) or specific methodologies for hypermedia like RMM (Isakowitz, Stohr & Balasubramanian, 1995), OOHDM (Schwabe & Rossi, 1998), and HFPM (Olsina, 1998) are not sufficient. They do not cover aspects relevant to personalization, i.e. user modeling and adaptation issues. A significant contribution in this field is AHAM (De Bra, Houben & Wu, 1999). AHAM is an application model for adaptive hypermedia that describe such applications from the point of view of the authors.

We propose the UML-based Web Engineering Approach (UWE) (Koch, 2000 & Koch et. al, 2001). UWE includes a design method for adaptive hypermedia applications (AHDM) and a development process for such applications (AHDP). UWE supports a systematic object-oriented design and development of adaptive hypermedia (Web) applications. In this way they differ from AHAM. We propose an integrated approach for object-oriented development of adaptive hypermedia

applications by presenting an extension to the Unified Modeling Language (UML). As basis for the software engineering approach we have developed the Munich Reference Model, i.e. a Dexter-based reference model which is formally specified using UML and OCL (Koch, 2000).

## **Our Approach**

By way of an analogy to hypermedia engineering (Lowe & Hall, 1999), *engineering for adaptive hypermedia applications* can be defined as a systematic, disciplined and measurable approach that supports the entire life cycle of adaptive hypermedia systems. This life cycle goes from conception through the elaboration, construction, delivery and maintenance to the cessation of the application.

The goal of an engineering approach is to support developers during these different phases in organizing mental activities, working at various levels of detail and abstraction, generating visual representations adapted to the designers level of experience, presenting the solution's constraints, building representations of the application and finally outlining plan structures and strategies.

The main motivation of our work was to define an engineering approach to adaptive hypermedia systems based on the object-oriented techniques that are state of the art in the software development. UML ([www.omg.org/uml/](http://www.omg.org/uml/)) – a standard for object-oriented software design since 1997 – was chosen for all models, techniques and notations used.

### **Reference model**

The aim of the Munich Reference Model is the formal specification of the features that constitute an adaptive hypermedia system and distinguish a high quality application. It is defined as an extension of the Dexter Hypertext Reference Model including a user model and an adaptation model. UML provides the notation and the object-oriented modeling techniques for the visual representation of the model. The Object Constraint Language (OCL), which is also part of UML, is used to supplement the semi-formal visual representation with semantic information. The formal description specifies invariants on the model elements and attributes as well as pre-conditions and post-conditions on the functions of the model. This formal specification is equivalent to a specification in Z, for example.

### **Design method**

Visual modeling techniques are introduced in this work to define methodical analysis and design of adaptive hypermedia applications. The methodology of the UWE approach consists of modeling elements, notation and a method. The method is proposed to support the systematic construction of adaptive hypermedia applications and to identify as many steps as possible to be performed in an automatic way.

The notation and semantics of these elements define a “lightweight” UML extension, a so called UML profile. It is defined as a set of stereotypes and properties for adaptive hypermedia that are used in some of the models proposed by UWE for the analysis and design. These models are: a conceptual model to define the content, a user model, a navigation model, a presentational model to define static and dynamic aspects of the presentation and an adaptation model.

UWE is characterized by the separate treatment of hypermedia issues, such as content, navigation and presentation and from user modeling and adaptation issues.

### **Development Process**

The development process of our approach, is based on the Unified Process; UWE adapts the Unified Process to support the development of hypermedia (Web) applications in general and to include special activities needed in the development of adaptive systems.

UWE describes an object-oriented, workflow-based, user-centric, systematic, iterative and incremental process. Each workflow is textually and graphically described. Both include workers, activities and artifacts. The latter is represented by an activity diagram. UWE specializes the Unified Process for the development of adaptive hypermedia applications describing which “experts” (workers) are required, which activities they perform and which specific artifacts they produce. UWE extends the coverage of the Unified Process development cycle adding a maintenance phase and a quality management workflow. It changes the idea of quality control management incorporating workflows for requirements validation and design verification in addition to testing.

The design techniques are embedded in the UWE development process, which aims to cover the entire lifecycle from inception to maintenance of adaptive hypermedia applications.

### **Case Studies**

The engineering approach was validated using several case studies, e.g. SmexWeb, an adaptive exercising system for students of a computer science introduction course ([pst1.pst.informatik.uni-muenchen.de:8000/indexE.html](http://pst1.pst.informatik.uni-muenchen.de:8000/indexE.html)). SmexWeb is a framework developed at the Institute of Computer Science of the LMU that permits the development of teaching applications through instantiation. It supports adaptive content and adaptive navigation in all its variants (Brusilovsky, 1996). In addition it allows the system to take control over the process of navigation under special conditions (passive navigation), such as a period of user inactivity (Albrecht, Koch & Tiller, 1999).

Currently we use the UWE approach in the LAMP project for designing and implementing an adaptive tutoring system for several Bavarian Universities ([www.pst.informatik.uni-muenchen.de/projekte/lamp/index\\_e.html](http://www.pst.informatik.uni-muenchen.de/projekte/lamp/index_e.html)).

### **Open Issues**

The proposed engineering approach focuses on modeling and processes, but there are many open issues from the software engineering point of view, which still need to be addressed and integrated, such as implementation techniques for adaptive hypermedia or personalized Web applications.

The development process requires case tool support. Tools for UML are developing fast, but they need to include special features for Web development since Web applications are becoming in a near future the most frequently developed software applications.

Our objective is, for example, to implement the stereotypes defined for (adaptive) hypermedia and Web applications (Koch,2000) as a plug-in feature of the open-source tool ArgoUML (argouml.tigris.org).

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