# Software Engineering for Adaptive Hypermedia Systems:

## Reference Model, Modeling Techniques and Development Process

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This PhD thesis focuses on the development of "*personalised" hypermedia* applications. Personalisation, also called customisation or adaptation, is the process, which – when applied to software – consists of a change in the behaviour of the software system based on the knowledge the system has of the user. This knowledge can be supplied by the users themselves or by the software system, which is prepared to observe and register the user's behaviour. Software systems with the capability to acquire information about the user, to build a user model with it, and to utilise the user model to dynamically adapt themselves are called *adaptive systems*. Adaptive hypermedia systems (AHS*)* are both adaptive and hypermedia systems. They combine hypermedia with Intelligent Tutoring Systems (ITS) guidance, through the adaptation of the information presented to the user, the layout of the presentation or the way in which the information units are visited, i.e. how navigation is performed.

The essential feature of hypermedia (also of the Web as a special hypermedia system) is the concept of a *network* of nodes connected by links. We could then define adaptive hypermedia applications as those that adapt the content or presentation of their nodes and/or their links to the user. The advantage of the hypermedia style of structuring and accessing information has, however, some limitations and shortcomings for users and developers. The disadvantages for the users are an easy disorientation – the so called "lost in the hyperspace" syndrome – and the cognitive overload.

*Adaptive hypermedia systems* seek to solve these problems by adopting a user-centred approach. The user is observed by the system, a user model is built for the individual user, and the system adapts visible aspects of the system to the user. More precisely, the adaptation of the content and presentation avoids cognitive overhead by showing the appropriate information with the adequate layout to the individual user. Adaptive navigation solves the disorientation problem by limiting browsing space, providing annotations for the links, hiding some irrelevant links or suggesting the best link to follow. From the commercial point of view, personalisation has the advantage to draw new visitors, to turn visitors into buyers, to increase revenues and advertising efficiency. Most of the current adaptive hypermedia applications have been implemented as prototypes and improved in successive steps. We then need a process to perform the development in an effective and efficient way.

## Goal: An Engineering Process for Adaptive Hypermedia Applications

Adaptive hypermedia applications are complex software systems whose development process demands an exhaustive feasibility study, adequate planning and experience in the construction of hypermedia applications, user modeling and adaptation techniques; that means they require an engineering process. This work was motivated by the lack of such a software engineering approach for adaptive hypermedia systems.

A first natural decision was to consider only object-oriented techniques due to the popularity they gained during the last years. A second one was to chose the standard UML (Unified Modeling Language) as the modeling language for the complete work, decision that implies the use of OCL (Object Constraint Language) which is part of the UML, as formal specification language.

Why is a specific engineering approach required? General object-oriented software engineering approaches, such as the Unified Software Development Process (Jacobson, Booch & Rumbaugh, 1999) and the Rational Unified Process (Kruchten, 1998) or specific methodologies for hypermedia like RMM (Isakowitz, Stohr & Balasubramanian, 1995), OOHDM (Schwabe & Rossi, 1998), and HFPM (Olsina, 1998) are not sufficient as they do not cover user modeling and adaptation issues. Instead the approach of Wu, Houben and de Bra (1999) cover specific adaptive aspects, but they neither use object-oriented techniques nor address a process allowing the systematic development of adaptive applications. None of these methodologies are based on a formal specification.

The proposed software engineering approach is called UML-based Web Engineering (UWE). It focuses on the process and on object-oriented modeling. Implementation aspects are not considered because of the fast evolution of the implementation technologies and platforms.

## Result: The UWE Approach

Engineering for adaptive hypermedia applications – by way of an analogy to hypermedia engineering (Lowe & Hall, 1999) – 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 UML-based Web engineering (UWE) approach supports project managers and developers during these different phases in building a team with the appropriated skills, organising activities, modeling at various levels of detail and abstraction, outlining plan structures and strategies, presenting the solution's constraints, modeling the application, testing it and finally guaranteeing the maintenance of the application built.

The main results of the UWE approach are a *reference model* for adaptive hypermedia systems, a set of *modeling techniques* for the analysis and design of such applications, and a *development process* that covers the entire lifecycle of these applications. The validation of the engineering approach was done using a case study of one exercising session of the adaptive exercising system SmexWeb (Albrecht, Koch & Tiller, 2000).

The *reference model* for adaptive hypermedia applications was elaborated in order to identify the features that characterise adaptive hypermedia and personalised Web applications as a previous step to the definition of appropriate modeling techniques. It is named after the place where it was developed: Munich Reference Model.

The main characteristics of the *Munich Reference Model* are:

- It is based on the Dexter Hypertext Reference Model.
- It includes a user model and an adaptation model.
- It is an object-oriented reference model.
- It is formally specified in OCL and visually represented in UML.

The *modeling techniques* of the UWE approach for the methodical analysis and design of adaptive hypermedia applications comprise modeling elements, their notation and a method to build a set of models. Prior to the definition of these modeling techniques, existing techniques and the more relevant methodologies for general hypermedia have been compared. The survey analyses how these engineering approaches cover the hypermedia applications lifecycle, which techniques and notations they use, and which are their strengths and weaknesses.

The notation and semantics of the modeling elements presented in this work define a "lightweight" UML extension – a so-called UML profile. The analysis and design method supports the systematic construction of adaptive hypermedia applications. The aim was to obtain a method that allows as many steps as possible to be performed in an automatic way (Hennicker & Koch, 2000).

The main characteristics of the UWE *modeling techniques* are:

- It supports visual and systematic modeling.
- Hypermedia issues, such as content, navigation and presentation as well as user modeling and adaptation issues are treated separately.
- It provides a UML profile based on the extension mechanisms of the UML and uses it for the construction of the analysis and design models.

These modeling techniques were developed during the initial phase of this project and are also known as UML-based Hypermedia Design Method (UHDM). They are now integrated in the analysis and design workflows of the UWE *development process*. This process tailors the Unified Process for the hypermedia (Web) domain and for adaptive hypermedia in particular. At the same time it extends the Unified Process to include project management and quality management support.

The main characteristics of the *development process* forming part of the UWE approach are:

- It is an object-oriented, workflow-based, iterative and incremental process.
- It specialises the Unified Process for the development of adaptive hypermedia applications describing which "experts" (workers) are required, which activities they perform and which specific artifacts (models, products and documents) they produce.
- It extends the coverage of the Unified Process development cycle including a maintenance phase.
- It adds development process supporting workflows for project management and quality management.
- It changes the idea of quality control management incorporating workflows for requirements validation and design verification in addition to testing.

In summary, this work presents UWE, an object-oriented engineering approach for adaptive hypermedia systems. Part of this approach is a Unified Process based development process covering the whole lifecycle of adaptive hypermedia applications. Special emphasis has been put on visual modeling, the definition of an appropriate UML profile and a formal object-oriented specification of the reference model. The PhD thesis includes a detailed case study used to validate the modeling techniques and the development process that are proposed.

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