Adaptation in E-Learning Environments through the Service-Based Framework and its Application for AdeLE

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Abstract: E-learning may provide a lot of useful features in a wide range of learning and teaching situations. However, the provision of static learning material will not meet the requirements of the users. We believe that well-tailored, highly personalized learning sessions are needed. Regarding to this background, the research project AdeLE (Adaptive e-Learning with Eye-Tracking) aims to develop and implement a solution framework for personalised adaptive e-learning based on real-time user behaviour. In this paper we introduce the Service-Based Framework (SBF) - a reusable, scalable and flexible architecture for adaptation systems - and point out its application for AdeLE.

Introduction

E-learning paradigms and implementations have brought many advantages to technology-based distance education as pointed out in (ADL 2001). In addition, e-learning was identified as one of the emerging areas in the last few years as shown by means of concrete numbers in an IDC study (IDC 2003). On the one hand, e-learning enables identifying, analysing and monitoring relevant aspects of instructions, such as different velocities, paths, or strategies of learning. On the other hand, such parameters may be used to adapt the learning process to individual learners, and therefore, performance improvements within the learning process can be gained. We should also keep in mind that e-learning in general as well as tracking the users' behaviour and analysing their learning progress are not new research issues, but were demonstrated in classic systems such as CLASS and PLATO, see (Crowell 1967) and (Modesitt 1974). However, (Baumgartner 2003) reports about a lot of failures and only a few - in most cases locally restricted - success stories in the field of e-learning, and as stated in (Dietinger 2003), adaptive e-learning is not well-established yet.

According to our former experiences in e-learning, we believe that adaptation and personalisation will improve the learning process. Therefore, a paradigm shift from consumption of static learning contents to well tailored and highly personalized learning sessions is needed. We advocate the support of distinct theories or paradigms by adaptation-capable e-learning environments, e.g. *constructivistic* (Wilson and Lowry 2000), *serial* or *symmetric* (Jain et al. 2002), *discovery* or *managed* (Lennon and Maurer 2003) learning. Furthermore, an e-learning system should allow users to change dynamically its adaptation parameters as well as the system should adapt to the users automatically based on the system's assumptions about users' needs: as stated in (Oppermann et al. 1997), the former type of system stated is called *adaptable*, the later is named *adaptive*. We define an adaptation system as an environment of software modules, which comprises a set of features for adaptivity and adaptability.

Over the last decades various types of adaptation systems and possible areas for their applicability have been identified, thus leading to the emergence of specialised research fields, like AHS (Adaptive Hypermedia System), CAI (Computer Aided Instruction), CMI (Computer Managed Instruction), recommender systems, ITS (Intelligent

Tutoring Systems), PSI (Personalized Systems of Instruction) and many others. Adaptive multimedia systems as an improved learning environment is well documented in research work, as in (Brusilovsky 1998) and (Hothi and Hall 1998), implementation concepts and systems can be found for example in (Beaumont et al. 1995), (ARIADNE 2003) and (Cristea and deBra 2002). In (Conlan et al. 2002) user modelling techniques gain great importance for e-learning environments as they allow systems to customize the interaction between the learner and the content repository. Various solution approaches for modelling users and managing their profiles have been successfully developed. There are also well-known learner model standards and specifications, like PAPI (PAPI 2000), IMS-LIP (IMS LIP 2001) or GESTALT (Gestalt 1999). Furthermore, several technical solutions for adaptive systems have been established, like *shadowing* (Hothi and Hall 1998), *hiding links* (Brusilovsky 1998) and *stretchtext* (Boyle et al. 1998). Thus, a large number of research and development work from which other projects may benefit seems to exist. But, if there is that much already done, why is it so difficult to reuse, integrate or extend existing solutions?

Our intensive survey work has shown that many solutions – or solution approaches – are linked to predefined or very specific aims and validity limitations, so they are tailored just for a very specific application or application domain. Of course, the efficiency, applicability, validity range or performance of many existing techniques, in particular application domains, is demonstrated, because these and other features have already been evaluated and compared, as for example in the following fields: adaptivity degree for AHS in (Cini and Valdeni 2002), comparison of techniques for recommender systems in (Burke 2002), evaluation of user models (Chin 2001), Bayesian algorithms for student modelling (Millan and Perez 2002), analysis of commercial personalisation servers on the WWW (Fink and Kobsa 2000) and (Kobsa and Fink 2003), evaluation of adapted hypermedia techniques using static user modelling (Hothi and Hall 1998). Thus, the research community gives excellent answers to complex problems, but the practical results, i.e. the implemented systems, are not always suitable or accessible for *reutilisation*.

All reasons and statements depicted so far led us to propose and develop the model of a *Service-Based Framework* (SBF) for adaptation systems. From the technological point of view of e-learning and as will be further depicted in the section 'Application of the Service-Based Framework for AdeLE' of this document, our research project AdeLE (Adaptive e-Learning with Eye-Tracking) may be seen as a step into a new *integrational learning paradigm*. Thus, the SBF in AdeLE enables on the one hand the integration of different didactical methods on a modular and flexible system, and on the other hand, it enables the definition and implementation of a reusable and scalable architecture. In particular, the following sections of this paper represent an introductory overview over the applicability of the SBF to adaptive e-learning.

The Service-Based Framework (SBF)

In order to find a general architectural solution for the AdeLE research project, some basic technical requirements had to be stipulated and evaluated. As a result, the idea behind the conceptual design of the technical architecture of AdeLE is based on the following software system requirements:

- Easy extensibility
- Open interfaces
- Strict modularity
- High scalability
- Encapsulation of different scopes of functionality
- Specialisation of functional ranges, i.e atomicity of software components
- Ability to (easily) integrate networking functionality
- Exchangeability and replaceability of software components
- Utilisation and (easy) integration of well-established Standards
- Easy and standardised combination of atomic software components
- Ability to solve complex tasks through combination of atomic software components
- Easy and standardised combination of system modules
- Interchangeability with external system modules

There already exist some technologies and standardised solution approaches, which fulfil some of the above stated requirements, as for example Web Services (Booth et al. 2004), JXTA (JXTA 2004), DINO (Schmaranz 2002), CORBA (OMG 2004), JINI (SUN 2004) and more. The key issue in the context of this paper is represented by the requirement *atomic software components* (ASC). We define the meaning of an ASC as the smallest software unit, which is able to provide the needed functionality to solve a very specific problem. Some existing technologies refer to such specialised units as ‘services’, ‘components’ or e.g. ‘agents’. ASCs are often found in relation with distributed systems, peer networks, agent-based architectures, middleware and the like. The list of literature references to these solution alternatives is very large, so we confine ourselves to mentioning that there is extensive development, standardisation, implementation and enhancement work behind these well-established technologies.

Web Services represent a very flexible, platform independent and standardised technology for distributed components. JINI shows performance advantages compared with Web Services by means of network traffic, service look-up and others; this behaviour relies on the fact that JINI’s framework is restricted to Java. Another important issue in the context of our project is the management of knowledge units in e-learning environments, i.e. the management of semantically and pragmatically enhanced information; also here we want to refer to some other research and standardisation works, as for example KOD (Sampson et al. 2002), SeLeNe (SeLeNe 2004), AEHS (Dolog and Henze 2003) and DAML-S (Sollazzo et al. 2002). Our proposed framework, the Service-Based Framework (SBF), takes into account and - where possible and meaningful - tries to merge or extend the main ideas behind the above depicted technologies and research works. In this paper, only a brief overview of the SBF is given in the following sections.

The general model of the SBF architecture is shown below in figure 1. Regarding the technical requirement for AdeLE concerning its easy scalability and flexibility, we define ASCs as the smallest functional units and call them *services*. Services are represented at the lowest level in figure 1 by the small dark-grayed circles in the Service Pool layer.

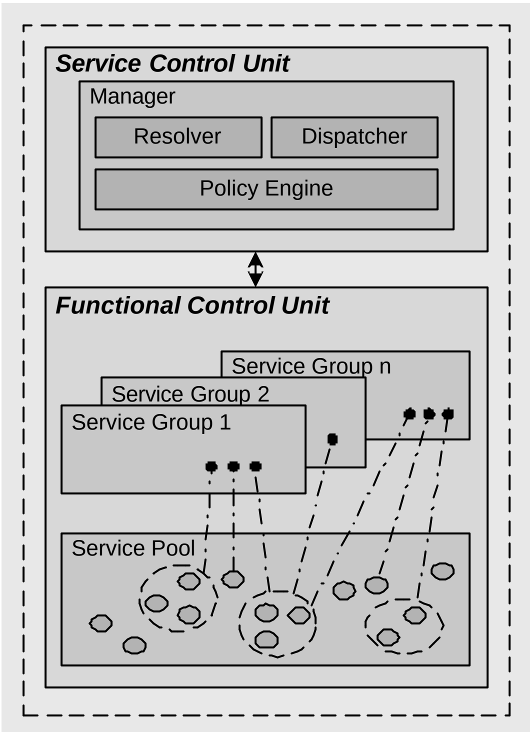

Figure 1: The general architecture of the Service-Based Framework (SBF)

Services in AdeLE are the mechanisms to encapsulate specialised functionality units and are characterised by the following behaviour: services know exactly ‘how’ to perform specific tasks, but they do never know ‘when’. In order to define other services, which are in charge of more complex tasks and need the operability of ASCs, the SBF allows the *reusability* of services, building so-called *composite services* (CS). This issue is shown in the lowest part of Figure 1 (see dashed circles in the Service Pool layer). Services and composite services span a space of functionality units, which we call *Service Pool* (SP). In order to organise several services and CSs that belong to a common application or serve as a specific contextual sub-framework, the SBF provides the possibility of reassembling such units to a *Service Group* (SG). Thus, these mechanisms allow the specification and implementation of separate application modules and enhance the system by means of scalability, flexibility, modularity, extensibility, interchangeability and functional encapsulation. For the purpose of modelling these basic functional capabilities of the system we embrace the just mentioned features in a so-called *Functional Control Unit* (FCU, see Figure 1).

The upper part of Figure 1 shows the *Service Control Unit* (SCU), which is described by a *Manager*. The Manager comprises the basic tasks of dispatching and resolving the functional management of the modules in the FCU. As already mentioned, services do not know when to actuate. The manager is responsible for the controlled and monitored registration, look-up, interaction, synchronisation and execution of services or CSs. Thus, the above depicted problem of 'when' to switch services is delegated to a general control unit that can resolve the functional and structural scope of the FCU. The duty of dynamic binding of new services is also assumed by the FCU. Furthermore, the SCU dispatches the requests from external systems and monitors the correct execution of services. For this purpose, the SCU is mainly divided into the modules *Dispatcher* and *Resolver* (see upper part of Figure 1). The very important issue regarding the protection of transferable data is also incorporated in the SCU and is implemented by the *Policy Engine* (PE). The PE is defined by rules and policies, which are interpreted and applied to the FCU-output in order to filter information pieces that may not be negotiable to external systems.

The SBF provides also mechanisms to define the *activation type* of the members of the FCU, i.e. a service or a CS may be activated as a *scheduled*, *event-driven* or *message-driven* task. A scheduled service can be seen as the definition of scheduled methods or cron jobs, and its monitoring is adopted by special processes in the Dispatcher module. If an event-driven service is requested, then the manager acts as a mediator and monitors the related event-dependent service tasks. Message-driven services are intended to interact with other modules or systems in order to transfer e.g. data structures or functional parameters.

As can be seen, the SBF comprises very fundamental and easy-to-manage features by enabling at the same time the extensibility of its functionality scope by means of services implementation and reassembly. The problem of syntactic or semantical dependencies (side-effects) among services can be solved through the definition of specific negotiation services in form of a CS. The next section gives an overview of the applicability of the SBF to the AdeLE architectural framework.

Application of the Service-based Framework for AdeLE

In brief, AdeLE is an adaptive e-learning system by using an enhanced and fine-grained user profile analysing user behaviours and user states in real-time. One of the interesting and novel features of AdeLE is the application of real-time eye-tracking information in combination with fine-grained content tracking. More detailed information can be found e.g. in (García-Barrios et al. 2004). Taking into consideration the general system requirements listed in the previous section, the main objectives of the AdeLE research project in the context of this paper can be summarised as follows: (1) *open system provision* in terms of open interfaces, interchangeability of subsystems and modules, (2) *easy interchangeability and extensibility of features*, (3) *task-specific separation and specialisation*, (4) *platform independence*, (5) *high scalability* and (6) *easy integration* of existing applications or external systems. The main objectives stated so far make it possible to apply the Service-Based Framework (SBF) as discussed in the following paragraphs.

Architecture of AdeLE

The core implementation of e-learning features supporting adaptation and the application of the SBF is located at the server-side of the AdeLE system. For this reason the focus of this paper is represented by the server-centred architectural overview of the framework, as depicted in Figure 2.

At the client-side of the AdeLE framework, the web browser renders the e-learning content and enables the user to interact with the content. At the same time, real-time information about user behaviours and constitutional states is collected and compressed at the client-side. At the server-side the input for the *Profiler System* consists of user information received from clients' input devices as well as information about the user's interaction gathered from *Learning Management System (LMS)* via *Adaptation System*. These functional issues define the adaptive behaviour of the system. In addition, external interaction by teachers and tutors may allow to influence the behaviour of the system at run-time, e.g. to enforce the provision of particular learning material. This intervention features enhance the adaptation of the system by means of dynamic adaptability. Vice versa, the *Profiler System* delivers the basic information to the *Adaptation System*. Furthermore, the *LMS* is controlled by the *Adaptation System* and delivers the user-adapted content to the client-side. *Profiler System* and *Adaptation System* are instances of the Service-Based Framework. Both will be discussed in the following paragraphs.

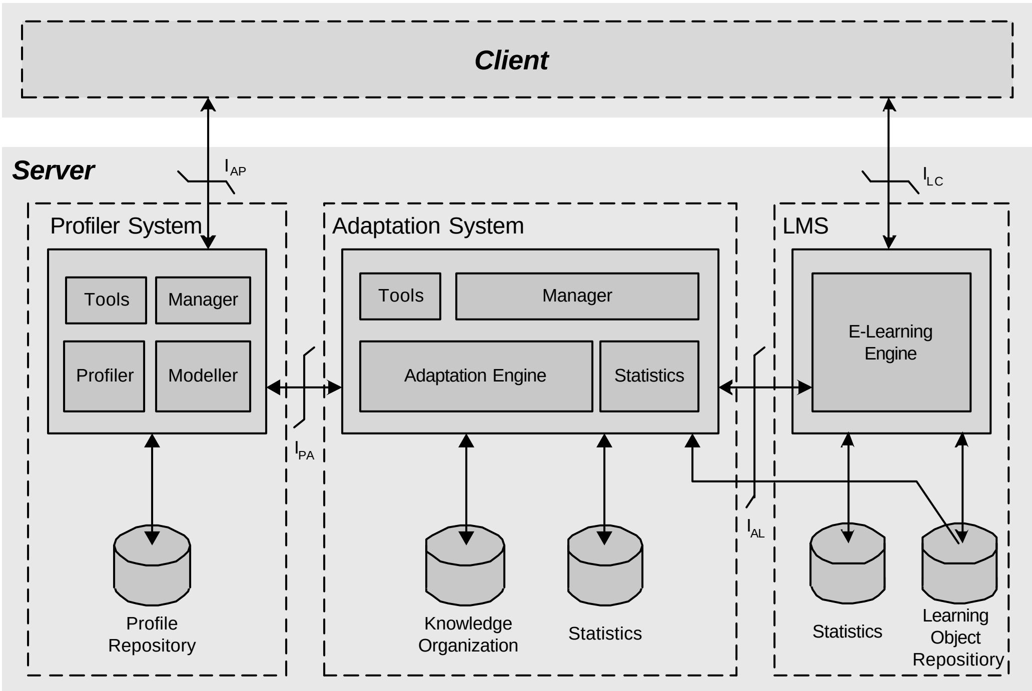

Figure 2: Server-side Architecture of AdeLE

Profiler System

The *Profiler System* is server-sided and communicates with the client and the *Adaptation System* as shown in Figure 2. Based on the collected information about the user behaviour, the *Profiler System* manages user and group profiles of both, learner and teacher, and provides necessary user models, which can be seen as an extended view on a profile for the adaptation steps performed by the *Adaptation System*. The system consists of the modules *Tools*, *Manager*, *Profiler* and *Modeller*. As described in the section about the Service-Based Framework, the module *Manager* encapsulates the functionality to register and monitor the services of the *Profiler System*. The FCU in the *Profiler System* is determined through the system modules (service groups) *Tools*, *Profiler* and *Modeller*. The module *Profiler* manages all kind of profiles and the *Modeller* implements one or more user models, which enriches the profiles with semantic or pragmatic information. The *Profiler* gathers and organises existing attributes of a profile or integrates new ones. The *Modeller* in turn has to organise the knowledge (e.g. in terms of thesauri or knowledge domains), generate semantics (e.g. using AI-techniques) or assemble profile data to complex data structures. The *Tools* module is in charge of enabling functional extensibility to the *Profiler System* by means of provisioning of services that do not concern directly the functional application scope of User Profiling or User Modelling, e.g. implementing a profiler editor or supporting different data interchange standards.

Based on the SBF, two outstanding advantages can be pointed out. First of all, the *Profiler* and the *Modeller* can be separated with regard to a logical view using the concepts of *service groups*. Secondly, the tasks of these two modules can be implemented with *services*. This means that additional or further functionality could be implemented by deploying further specialised services or *composite services*. Furthermore, the flexible SBF-based *Profiler* enables the design and implementation of a general object-profiler or object-modeller, which can be used for multiple purposes, e.g. learner profiler, teacher modeller, group profiler and even for completely different tasks like course-profiler or instruction-modeller.

Adaptation System

As shown in Figure 2, the *Adaptation System* is the central component of the AdeLE architecture. It is in charge of interchanging information with the *Profiler System* and controlling the *LMS* in terms of the adaptation to the user. Therefore, the *Adaptation System* is ordered in five logical modules: *Manager, Config, Adaptation Engine, Tools* and *Statistics*. The module *Manager* provides methods to register the services as well as to monitor them. The Manager represents the SCU by means of the SBF. The module *Config* is necessary to configure the default functionality of services, composite services and service groups. Thus, this special module comprises the static adaptability of the e-learning environment. The *Adaptation Engine* is the most important service group for the adaptive behaviour. This module is responsible for gathering all necessary input parameters like the learner's interaction with the *LMS*, the available course content, the information of the *Profiler System* as well as the dynamic interventions by teachers and tutors. Based on all this information, the *Adaptation Engine* can determine the next step for the learning process, e.g. it could provide necessary information for the *LMS* or generate the next page to display. The adaptation rules itself could be derived from dependencies between the content, the learner's profile and the teacher's intentions that are stored in an own repository called *Knowledge Organisation*. The module *Statistics* is needed to record more specific statistical information about adaptive e-learning than the equivalent module of the *LMS* can do. Finally, the *Tools* module is in charge of enabling functional extensibility to the *Adaptation System* by means of provisioning services that do not concern directly the functionality scope of the other modules in the FCU.

Similar to the *Profiler System*, the SBF is also advantageous for the *Adaptation System*. As already pointed out, the services of the modules can be combined using the concept of service groups. Based on the SBF, the *Adaptation Engine* can provide services for gathering all necessary information, creating models for adaptation, sampling, presenting and sequencing the learning objects as well as distributing the results. Besides, the *Statistics* module has to realise services for the enhanced learner tracking, creating a model to evaluate the statistics, analysing the collected data and providing statistics to other systems. Furthermore, the SBF allows a very flexible way to adapt the *Adaptation System* itself to the *LMS* as well as to the underlying e-learning standard as will be shown in the following subsection.

Learning Management System (LMS)

The *Learning Management System (LMS)* extended by the *Adaptation System* provides the main functionality of the adaptive e-learning environment. On the one hand the *LMS* is the facilitator between the learner or teacher and the e-learning content. On the other hand, the *Adaptation System* is responsible for adapting to the learner and the teacher on basis of the user interaction observed by the *LMS*, the course content within the learning object repository, the user profile information as well as the influences on the learning process by the teacher. It is worth mentioning that AdeLE uses these input parameters to provide adaptivity on two levels: (a) first of all, the e-learning environment should adapt to the learner's characteristics and targets as described in (Brusilovsky 1998), and (b) it is important to adapt towards didactical guidelines given by the teacher within the e-learning content or by influencing the learning process directly as well as using collaborative tools to communicate with the learner.

One of the critical aspects of AdeLE is the possibility to extend the functionality and semantical scope of any *LMS* with regard to adaptive e-learning. Therefore, the coexistence between *Adaptation System* and *LMS* has to be highly scalable. The *Adaptation System* has to be able to handle the following three scenarios. First of all, the *LMS* may already implement adaptive behaviour, so in this case, the *Adaptation System* may serve as information provider. Secondly, the *LMS* may provide a set of commands to be controlled by the *Adaptation System*. Finally, the *Adaptation System* has to implement the real functionality of the *LMS*, like sampling the content, defining the navigational elements, and the like. In the latter case the *Adaptation System* has to control the *LMS* based on the content or other e-learning features. Beside these three scenarios of the *LMS*, the *Adaptation System* must also be able to understand the contents that generally follow a standard in the field of e-learning (see Dietinger 2003). Hence, the *Adaptation Engine* could provide a service for each specification of the underlying standard. Relating to all these aspects, the SBF can be seen as a powerful framework to be able to adapt the *Adaptation System* itself to the *LMS* and the content in a very flexible way.

Conclusions and Future Work

Adaptive e-learning tends to be a promising approach to improve the knowledge transfer processes in a wide range of application fields. However, a lack of important adaptation features in present e-learning environments can be identified. In the field of general adaptation systems, many solution approaches are linked to specific technological or functional aims, so they are tailored just for a very specific application domain.

Taking into account the lack of reutilisation of existing solution implementations, we have proposed the development and utilisation of a *Service-Based Framework* (SBF) for adaptation systems. The aim of the SBF is to enable the definition and implementation of a reusable, scalable and flexible architecture for adaptation-supporting systems. In particular, we have shown in this paper the applicability of the SBF to adaptive e-learning systems. Some of the main advantages of the SBF can be identified as follows:

- Other research groups may benefit from the SBF by means of reusability or interchangeability of results.
- The modular separation of application-dependent functionalities within an adaptive system may be carried out through the definition of service groups.
- The SBF enables the implementation of atomic software components and allows therefore the easy-to-manage addition of functionality units to a 'running' system.

The application of the SBF in the research project AdeLE has shown that the basic concept meets the requirements for a modern adaptive e-learning system. The main advantages of the SBF within the scope of the research project are the flexibility and the extensibility of the framework. Furthermore, the application of the framework reduces implementation efforts, because two instances of the same basic functionality may be established in a comfortable and efficient way (as in the case of the Profiler System and Adaptation System in AdeLE).

The concrete implementation of the SBF inside AdeLE is being undertaken on the basis of the service-oriented framework Openwings (see http://www.openwings.org), which is a set of open systems specifications that enables the development of highly available, secure, distributed systems. One of the most interesting features of Openwings is reflected by its support of different "service-oriented" technologies, like Web Services, Jini (SunOne), .NET or JXTA. Thus, different types of services may be implemented, as e.g. JINI (LAN services), JXTA (Peer services), J2EE (transactional services), .NET (Web/LAN services) or R2D2 (real-time services). Currently, we are testing the technical and conceptual applicability of these mechanisms into AdeLE.

For future work, we will add to the Service-Based Framework a toolset of basic and general functionalities for adaptation systems and will release the source code as well as a basic documentation under GPL.

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