Semantic Web-based Adaptive Hypermedia

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Abstract

Adaptive Hypermedia constitutes a large portion of the Web nowadays. Issues of personalization and adaptation become crucial for the efficient handling of the information on the Internet. However, current hypertext reference architectures still lack appropriate modularization and expressiveness in order to meet all the challenges of Web dynamics. In the same time, standards and technologies resulting from the field of Semantic Web and Web Engineering offer flexible solutions, applicable also to the needs of Adaptive Hypermedia. In this paper we present our view on how the current development of knowledge engineering in the context of Semantic Web can contribute to the better applicability, reusability and shareability of adaptive Web-based systems. We propose a modular Semantic Web-based Adaptive Hypermedia architecture as a service-oriented framework for adaptive Web-based systems. The main goal is to help the semantic enrichment of the information search and usage process and to allow for reasoning-based adaptive support of user activities. We illustrate our ideas in the context of the CHIME project [9] for Cultural Heritage in Interactive Multimedia Environments.

1. Introduction

Currently, the provision of tools to support users in coping with the complexity of the information space and the dynamics of the Web demands becomes a prime focus within the Web society. During the past decades we have been observing the success of different types of software systems, which adaptively support users in various activities, e.g. Knowledge-based Systems (KBS) [21,23], Information Retrieval Systems (IR) [3,25,27], Adaptive Hypermedia Systems (AHS) [5,11], Web-based Information Systems (WIS) [30]. The observed problem is that most of the 'intelligent' (knowledge-based) systems are built in a very application dependent manner and the process of their development is time consuming and not oriented towards sharing [4]. On the other hand IR systems propose useful and precise techniques to retrieve data, but they do not consider much the application of user features. Finally, AHS and WIS embrace the main principles of the Internet and offer a simple concept for adaptation and personalization of both the content and the navigation to the user needs and goals. The simple hypertext reference architecture [10,15], underlying these systems and aimed at a quick adaptive response, appeared to be very suitable for the early generations of Web environments. On the other hand it lacks the notion of solid knowledge and reasoning, which weakens the position of Adaptive Hypermedia Systems within the context of more dynamic adaptive systems. Both AHS and WIS lack the sophistication of the IR and User Modeling approaches, which appear not to be enough to capture various knowledge facets important for the assessment of the user's knowledge level in order to provide accurate adaptation [6,8].

Ideally what we need is a number of independent services which, when combined "on the fly", and can support any type of activity (at various levels of abstraction) of any type of user(s).

Traditionally the field of Artificial Intelligence (AI) implements and successfully applies elaborate modeling approaches in order to support users in the performance of their tasks [26,28]. Lately the field of Semantic Web approaches similar problems in a Web-oriented fashion. One of the key goals in both efforts is to decrease the complexity of modeling and engineering the 'intelligence' in adaptive Web-based systems and to open them up to various application domains. Formally specified models allow for better expressive power both in defining advanced architectures and in supporting complex authoring activities. Metadata standards and Web services allow and support the processing of Adaptive Hypermedia and its integration in the big 'Web family' of interoperating applications and shared content. The most current advances with OWL exploit the existing W3C standards for ontology and metadata representation (e.g. XML, RDF and RDFS) and add the primitives of description logic as powerful means for reasoning services. Web Services, on the other hand make use of this semantics and offer means for flexible composition of services (system components) and thus appear to be a useful solution for achieving the modularization.

In this context, we aim at providing flexible information access, presentation and maintenance to a broad range of users (individual and groups) in a way that is personalized in the context of the user's pursuing of goals and performing tasks. We argue that the future of Adaptive Hypermedia Systems lies in the modularity of the architecture and the openness to interoperate with other applications or components.

In this research we take an ontological approach to enable a shared understanding of concepts throughout the system and to provide semantic relationships between the information resources and the user's knowledge of (or interest in) them. We show how the simple concept of hypermedia can improve its adaptation strategies using AI methods and techniques. In other words, we offer an open and modularized architecture, which will be able to interact, exchange data and share components, and thus to achieve the interoperability across applications. For this, we also provide for semantically rich descriptions of the components' functionality and their internal formats. A key role in this architecture play shared User Model Servers, enabling the development of ambient intelligence and the large-scale user-oriented interoperability among different Web applications. It maintains a generic sharable (dynamic) user model serving as a communication point for the different systems [19,20]. The biggest challenge here lies in the sharing, synchronization and interpretation of the user model. This way the user's behavior within each system will be permanently evaluated and more detailed and richer user models will be achieved in order to allow for enriched adaptation and personalization of the content.

Our ideas are illustrated in the context of the Token2000 project for Cultural Heritage in Interactive Multimedia Environments (CHIME) [9] (partners are Vrije Universiteit Amsterdam, CWI Amsterdam, and Technische Universiteit Eindhoven). We show how by combining Semantic Web techniques (with their elaborate AI strategies) with the simplicity of hypermedia interaction we can achieve better efficiency in the engineering and the reasoning of adaptive Web-based systems.

2. Background

If we look at the cultural heritage domain and specifically the one of Dutch national museums, we quickly realize that the most artifacts are inaccessible to the general public and experts distributed around the world. Museums own many more artifacts than they can show in their main exhibition at one time. Large investments are being made to "capture" the artifacts digitally and to give broader access to the digitized material.

However, there are some limitations to the current approaches. First, they focus only on a single type of user, e.g. novice user in the Rijksmuseum ARIA system or expert user in the Rijksmuseum AdLib database. Second, there is a general lack of adaptation and personalization with respect to the user(s) preferences, knowledge level and interests in a specific area, as well as with respect to the goals and activities the user performs. Third, the system is unidirectional, i.e. "experts" input information into the system and "users" query this information. And finally, there is no integrated approach to synchronize the user profile and to facilitate the user querying more than one museum database.

An important aim of the CHIME project is to offer ways to remove these restrictions and to allow information to be presented to a broad range of users in a suitable way and to allow them to add their own information to the repository, while respecting the integrity of the original historical sources. This allows a decentralized approach to the enrichment of information in the repository by all its users and to the benefit of all its users. A central role here has the user and content modeling in a multi-task context.

2.1 Related Research

An early research initiative for *metadata annotation* of Web content is SHOE [18]. The idea was further elaborated in the CREAM framework [16], with use of ontology concept instances, considering evolving ontologies and offering annotation in a semi-automated way. Amaya Web editor [1] shows RDF-based mark-up of resources while being created. Annotea [2] also points out the advantages of a centralized server and exemplifies a good scenario for collaborating authoring agents within "closed" content spaces. Other examples of annotation systems are given by the CREAM-based Ont-O-Mat/Annotizer [16], MnM [29], Letizia [22], etc.

Next to the annotation of the content another rather labor-intensive part is the process of its *linking*. The Conceptual Open Hypermedia Services Environment (COHSE) [7] introduces an ontological reasoning service over domain concepts and their relationships in combination with a Web-based open hypermedia link service: this enables documents to be linked via metadata describing their contents in a conceptual hypermedia system. Another recent work inspired by COHSE is given by Magpie [12]. It illustrates an approach to facilitate various interpretation views on the same content with no prior mark-up, but by means of adding an ontology-derived semantic layer.

A contribution to the *interoperability* and semantic Web services is the research on DAML-S/OWL-S. In this approach the `ProcessControl` Ontology provides a process definition in terms of its state, initial activation, execution, and completion. The `ServiceModel`, on the other hand, provides means for describing the data flow and the control flow in case of a composite service, and the `ServiceGrounding` specifies the service access of information by communication protocols, transport mechanisms, etc. Another relevant approach for describing the role of Web services in system architecture is the Web Service Modeling Framework WSMF [14]. That research shows that Web services appear to be a useful solution for achieving the modularization. We can reach reasonable automation and dynamic realization of the main aspects of Web services (e.g. Web service location, composition and mediation) by extending them with rich formal descriptions of their competence (in standardized languages such as RDF or OWL). This way we can allow Adaptive Hypermedia Systems to reason about the functionalities provided by different Web services, to locate the best ones for solving a particular problem, and to automatically compose the relevant Web services for dynamic application building.

An interesting approach that could serve as the basis for a successful application of the Web service perspective on AHS architecture is given by an existing Web service framework like the Internet Reasoning Service (IRS-II) introduced by [24]. It enables the support capability-driven service invocation (e.g. find a service that can solve problem X) because of the explicit separation of task specifications (the problems which need to be solved), method specifications (the ways to solve problems), and domain models (the context in which these problems need to be solved).

Modeling the user and related cognitive processes is another important aspect in providing adaptation. Hank [33] allows sharing of the same user model among different adaptive systems and UserML [17] offers an XML-based exchange language based on an UserOL ontology. It serves as a protocol language between the user modeling service and other services and as a representation language for the user model.

2.2. CHIME

In the context of the CHIME project we adopt various aspects of the related research and to exemplify how ontologies and Semantic Web can improve the adaptation and the interoperability among Adaptive Hypermedia systems (AHS). Our main goals are: (1) to provide richer semantics for the adaptive support individual and group users, (2) to standardize the user modeling and adaptation, and (3) to provide reasoning services within distributed Web-based systems in order to finally enable shareability and interoperability among them. This is the first step towards defining a new class of Semantic Web-based Adaptive Hypermedia environments.

3. Semantic Web-based AH Architecture

Here we present our approach for achieving openness and modularity of AHS architecture. In order to enable different AHS to work together at different levels (e.g. conceptual, user model, and adaptation) we see the need for four main aspects:

- supporting a strict separation of domain model, application model, adaptation model and user model, in order to ensure a good modularization of the system components;
- maintaining generic sharable (dynamic) models, such as the user model, to serve as a communication point for different AHS,
- providing semantically rich descriptions of the components' functionality and their internal formats, in order to allow for interoperability among system components, and
- providing mechanisms to describe the management, i.e. coordination and orchestration, of the communication between the system components.

In Figure 1 we illustrate our vision of the modular architecture for adaptive Web-based systems. One of the first characteristic aspects we observe is that the different system components are all equipped with facilities to communicate with the (other) components in terms of service invocations. Bridges, in this architecture, are used here in accordance with the UPML framework connector definition, given by [13], in order to specify mappings between the different model services within the architecture. Ontologies also play an important role here in order to define and unify the system's terminology and properties to describe the knowledge of each system service. Each service can be specified by means of a corresponding ontology, and in this way a common ground for knowledge sharing, exploitation and interoperability among the services is provided. This leads to a highly modularized architecture which offers a high degree of flexibility.

3.1. User Model

In the case of adaptive systems the access to the *user model* via a Web service is a good example of this flexibility. It means that designers can design systems

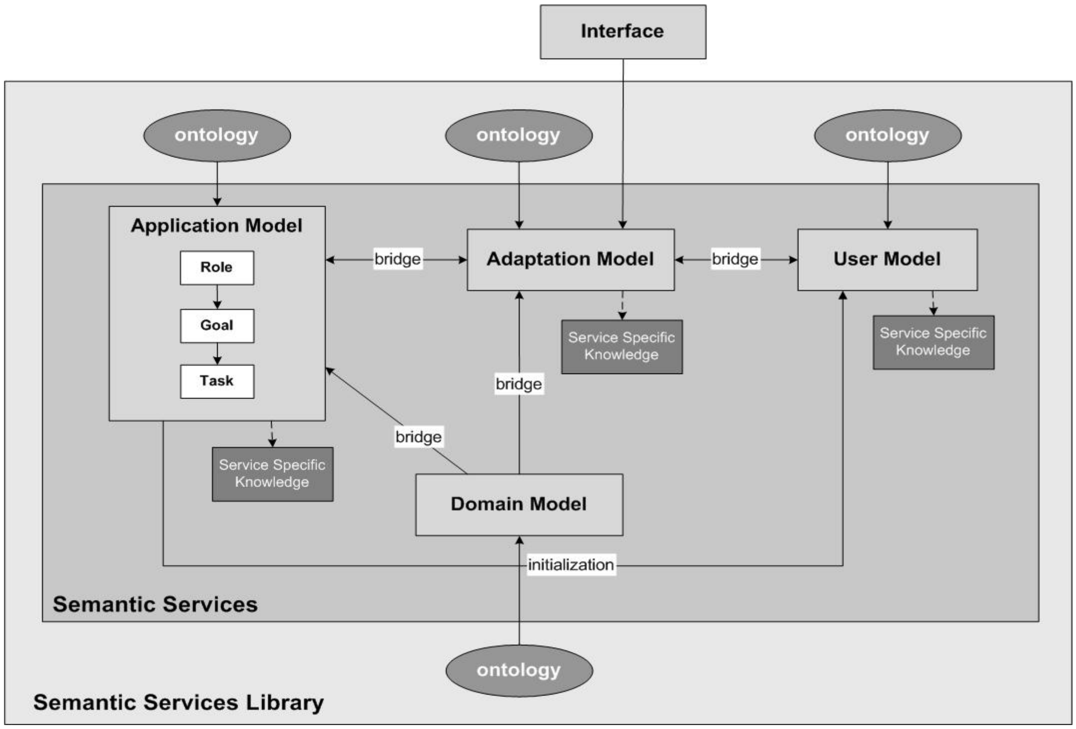

Figure 1. Semantic Web-based Adaptive Hypermedia Architecture

which will interact with or react to the user intelligently without knowing anything in advance about that user, but simply using the knowledge collected by other applications and interpreting it in the context of the current application.

Crucial for achieving such a flexible architecture is the need for a standardized protocol for encoding information about users. As mentioned above, open standards (e.g. XML, RDF, OWL) allow for the specification of ontologies to standardize and formalize meaning and to enable the reuse and interoperability. Another key aspect is the facilitation of the user models to be mobile and follow the user across applications. Results in the field of software agents provide implementation views supporting mobility and autonomous behavior. A final but important requirement is for the user modeling system to be able to reuse system and knowledge components, and thus benefit from other applications.

3.2. Component Services

A second characteristic aspect that we see in Figure 1 is the separation of the different components. In the traditional AHS approach, exemplified by AHAM, defined by [10] and [32], three sub-models are distinguished: domain model, adaptation model, and user model. When transforming these components into services the need for a fourth component, the application model, emerges. The main reason for this lies in the fact that in the traditional AHS approach the adaptation model unites the actual process of how to adapt with the decisions why to adapt. In most applications, e.g. those realized in AHA! [11], we see that the designer's knowledge about why the user is served in a certain way is more or less left implicit: the adaptation model implements the way in which the information is adapted to the user and does so based on the designer's decisions, which are not made explicit. In the situation where we want to share and exchange the different functionalities between systems, it becomes relevant to separate the "how" and "why" in the adaptation. While capturing in the application model the designer's intentions about the roles, goals and tasks in the application (related to domain model concepts and user model values), the adaptation model restricts itself to the actual realization of the adaptation to follow the directions given by the application model. In fact this aligns well with the proposal from the earlier mentioned IRS-II. The application model service contains a generic description of the user tasks in the context of a Role-Goals-Tasks model.

It is clear that this gives the application model service a crucial role in the system architecture. It divides the adaptation process into two parts, where the actual technical adaptation is performed by the *Adaptation Model Service*, while the management of the service process is coordinated from the *Application Model Service*. The entire architecture as displayed in Figure 1 emphasizes the fact that the core knowledge about the application processes and the user activities (tasks, roles and goals) lies in the application model service. In the interaction with the application the user is represented by a particular role (e.g. guest, a system expert, administrator, student). This role defines for him/her a corresponding behavior in the terms of goals to achieve. In order to accomplish those goals the user uses appropriate tools (applications), which realize one or several corresponding methods to achieve the user's goals. The adaptation model service is receiving the direct user input and interacts with the application model service in order to define the context for the user input for its most precise adaptation. Further the adaptation model service queries the domain model service in order to select the relevant content to be presented to the user. The domain model service is responsible for the explicit storage and description of the domain knowledge in terms of concepts of a domain ontology. Finally, it updates the user model with new values. For instance, when the users work with a selected application, every action they perform on the user interface is communicated to the user model service, which is responsible for the update of the user model with the new values. The user information is stored there and a reasoning engine infers new knowledge from it and makes predictions concerning future user behavior. In this way the user model service allows for sharability of the user model between applications by following the user (inside and outside the system) in order to collect and further analyze data about the user's activities.

4. Conclusions

In this paper we report on the work performed within the scope of the CHIME project. We adopted various aspects of the research related to IRS-II [24] and WSMF [13] in order to demonstrate how ontologies and Semantic Web Services can enhance the adaptation and interoperability of Adaptive Hypermedia systems. We realized this by focusing on three main aspects: (1) the provision of richer semantics for the adaptive support of both individual and group users, (2) the standardization of user modeling for adaptation, and (3) the facilitation of reasoning services within distributed Web applications. In this way, we are able to achieve a modularized Adaptive Hypermedia architecture, which allows for interoperability and sharing of both knowledge components among different AHS. The solution that we sketch here draws the first step towards defining a new class of Semantic Web-based Adaptive Hypermedia environments.

References

[1] Amaya Web Editor (2004). http://www.w3.org/Amaya/.

[2] Annotea (2004). http://www.w3.org/2001/Annotea/.

[3] Aroyo, L., Dicheva, D. (2001). AIMS: Learning and Teaching Support for WWW-based Education. In International Journal for Continuing Engineering Education and Life-long Learning (IJCEELL), 11, No. 1/2, 152-164.

[4] Aroyo, L., Mizoguchi, R. (2004). Evolutional Authoring Support Systems. Journal of Interactive Learning Research (JILR), Special Issue on Computational Intelligence in Web-based Education (in press).

[5] Brusilovsky, P., Eklund, J., Schwarz, E. (1998). Web-based education for all: A tool for developing adaptive courseware. Computer Networks and ISDN Systems. In Proceedings of 7th International World Wide Web Conference, 30 (1-7), 291-300.

[6] Brusilovsky, P., Maybury, M. T. (2002). From Adaptive Hypermedia to Adaptive Web. In P. Brusilovsky and M. T. Maybury (eds.), Communications of the ACM 45 (5), Special Issue on the Adaptive Web, 31-33.

[7] Carr, L., Bechhofer, S., Goble, C., Hall, W. (2001). Conceptual Linking: Ontology-based Open Hypermedia. In 10th World Wide Web Conference, Hong Kong,

[8] Chepegine, V., Aroyo, L., De Bra, P., Hardman, L., Nack, F., Schreiber, A., Valkovich, K. (2003). CHIME: Adaptive Framework for Semantic Web Service Integration. In InfWet'03 Conference, pp. 29-36.

[9] CHIME: Cultural Heritage in an Interactive Multimedia Environment.
URL: http://homepages.cwi.nl/~media/projects/CHIME/

[10] De Bra, P., Houben, G.-J., Wu, H. (1999) AHAM: A Dexter-based Reference Model for Adaptive Hypermedia. In ACM Conference on Hypertext and Hypermedia, pp. 139-146.

[11] De Bra P., Aerts, A., Berden, B., de Lange, B., Rousseau, B., Santic, T., Smits, D., Stash, N. (2003) AHA! The Adaptive Hypermedia Architecture. In ACM Conference on Hypertext and Hypermedia, pp. 81-84.

[12] Dzbor, M., Domingue, J. Motta, E. (2003). Magpie: Towards a Semantic Web Browser. LNCS 2870, Proceedings of ISWC 2003, pp. 690-705.

[13] Fensel, D., Motta, E., Benjamins, V.R., Decker, S., Gaspari, M., Groenboom, R., Grosso, W., Musen, M., Plaza, E., Schreiber, G., Studer, R., and Wielinga B. (1999) The Unified Problem-solving Method development Language UPML. ESPRIT project number 27169, IBROW3, Deliverable 1.1, Chapter 1.

[14] Fensel, D., Bussler, C. (2002). The Web Service Modeling Framework WSMF, White paper.

[15] Halasz, F., Schwartz, M. (1994). The Dexter Hypertext Reference Model. Communications of the ACM, 37 (2), pp. 30-39, 1994.

[16] Handschuh, S., Staab, S., Maedche, A. (2001). Cream – creating relational metadata with a component-based, ontology-driven annotation framework. In Proceedings of 1st International Conference on Knowledge Capture. ACM Press, pp. 76-83.

[17] Heckmann, D., Kruger, A. (2003). A User Modeling Markup Language (UserML) for Ubiquitous Computing. In Proceedings of User Modeling'03 Conference, pp. 393-397.

[18] Heflin, J., Hendler, J., Luke, S. (1999). SHOE: A Knowledge Representation Language for Internet Applications. Technical Report CS-TR-4078 (UMIACS TR-99-71), University of Maryland at College Park.

[19] Kay, J, Kummerfeld, R. J., Lauder, P. (2002) Personis: a server for user models, De Bra, P, P Brusilovsky, R Conejo (eds), Proceedings of AH'2002, Springer, 203 - 212.

[20] Kobsa, A. (2002) Personalized Hypermedia and International Privacy. Communications of the ACM 45(5), 64-67.

[21] Koedinger, K. R., Aleven, V., Heffernan, N. T. (2003). Toward a Rapid Development Environment for Cognitive Tutors. 12th Conference on Behavior Representation in Modeling and Simulation. Simulation Interoperability Standards Organization.

[22] Lieberman, H. (1995). Letizia: An Agent That Assists Web Browsing. IA-ED'95, Montreal.

[23] Mitrovic, A., Koedinger, K.R., Martin, B. (2003). A Comparative Analysis of Cognitive Tutoring and Constraint-Based Modeling. In 9th International Conference on User Modelling 2003, USA, pp.313-322.

[24] Motta, E., Domingue, J., Cabral, L., Gaspari, M. (2003). IRS-II: A framework and Infrastructure for Semantic Web Services. In Proceedings of 2nd ISWC'03.

[25] Page, L., Brin, S. (1998). The anatomy of a large-scale hypertextual Web search engine. Proceedings of the 7th Intl. WWW Conf., 107-117, 1998.

[26] Slaney, M., Subrahmonia, J., Maglio, P. (2003). Modeling Multitasking Users. In P. Brusilovsky et al. (Eds.): UM 2003, LNAI 2702, pp. 188.197.

[27] Sullivan, D. (2003) Search Engine Sizes. In Search Engine Watch, September 2, 2003.

[28] Sycara, K. and Zeng, D. (1995). Task-Based Multi-Agent Coordination for Information Gathering. In Working Notes of the AAAI Spring Symposium Series on Information Gathering from Distributed, Heterogeneous Environments. Stanford, CA, 1995.

[29] Vargas-Vera, M., Motta, E., Domingue, J., et al. (2002). MnM: Ontology Driven Semi-automatic and Automatic Support for Semantic Markup. In Proceedings of the 13th European Knowledge Acquisition Workshop (EKAW).

[30] Vdovjak, R., Frasincar, F., Houben, G.J., and Barna, P. (2003). Engineering Semantic Web Information Systems in Hera. Journal of Web Engineering, Vol. 2, No. 1&2, p. 3-26, 2003, Rinton Press.

[31] Weber, G., Brusilovsky, P. (2001). ELM-ART: An adaptive versatile system for Web-based instruction. IJAIED 12(4), Special Issue on Adaptive and Intelligent Web-based Educational Systems, 351-384.

[32] Wu, H. (2002) A Reference Architecture for Adaptive Hypermedia Applications, PhD thesis, Technische Universiteit Eindhoven ISBN 90-386-0572-2.

[33] Mulholland, P. and Watt, S. N. K. (2000). Learning by building: A visual modelling language for psychology students. Journal of Visual Languages and Computing, 11 (5), 481-504.