A Model Based on Semantic Nets to Support Evolutionary and Adaptive Hypermedia Systems

Natalia Padilla Zea[1], Nuria Medina Medina[1], Marcelino J. Cabrera Cuevas[1], Fernando Molina Ortiz[1], Lina García Cabrera[2]

[1] Dep. LSI. University of Granada, [2] Dep. Informática. University of Jaen - Spain
[1] {npadilla, nmedina, mcabrera, fmo}@ugr.es, [2]lina@ujaen.es

Abstract. The aim of this paper is to briefly describe a semantic, systemic and evolutionary model that has been conceived to develop adaptive hypermedia models. This model is called SEM-HP and it is composed of four subsystems which allow separating aspects related to knowledge representation, presentation, navigation, and user adaptation. Above this layer we have a “meta” layer which makes possible a consistent evolution of the elements defined in each of the four subsystems, as well as their automatic co-evolution.

Keywords: User adaptation, Hypermedia systems, Evolution software, Author tools

1 Introduction

Adaptive Hypermedia Systems (AHS) offer a big variety of advantages that turn them into very powerful tools. Some of the advantages of hypermedia technology are the associative retrieval of information and diversity of formats and ways to access information. Regarding adaptation, the main benefit is the ability to adjust the system to the characteristics and needs of each particular user. However, although they reduce many problems of the traditional hypermedia systems, such as user disorientation and knowledge overloading, others problems arise when we use AHS. On the one hand, changes in the link structure and in the content of the pages are not made on the users' demand. This may seem strange for some users who do not find what they expect. So, we think that the user must have some control over when and how the adaptation is carried out by the system. On the other hand, the AHS could force the user to read all the prerequisites for the desired information although this may not be needed. Therefore we believe that it is important to allow different types of navigation in the hypermedia system. In this way, the user can choose between navigation modes that are more free (weaker adaptation) or more guided (stronger adaptation).

In a similar way, building the AHS has some problems from the author's perspective. It is clear that the author's task becomes more difficult than in non-adaptive systems, but this disadvantage can be softer if we provide a suitable tool for authors. A bigger problem is that design, development and maintenance processes (the whole life cycle) of AHS are not given enough importance. In particular, some tools for authors do not incorporate a sufficient amount of mechanisms to make system changes easier during and after the development of the system. And most of them do not provide the necessary mechanisms to ensure that, after the changes have been made to the system, it remains in a consistent state.

The paper is organized as follows: Section 2 introduces the SEM-HP model. SEM-HP model is our proposal to build adaptive hypermedia systems, which guarantees a semantic correspondence between structure and functionality in the system and supports the author in the development and maintenance processes. Section 3 briefly describes the elements of the model, focusing on the architecture. Section 4 exposes some results and further work. Finally, section 5 outlines the conclusions.

2 SEM-HP Model

SEM-HP [1, 2] is a SEMantic, Systemic and Evolutionary model that allows the development of HyPermedia systems. In this model, the design and development processes are based on a cognitive model by which the author can characterize the knowledge domain of the hypermedia system (HS) by using his own onthologies. This is important in order to be in line with the efforts of the W3C and the IEEE LTTF towards the semantic Web, as do other authors in this field [3, 4 and 5]. At the same time, the model tries to make the development, maintenance and navigation of HS easier and more flexible. To do it the model divides the design of the HS in four phases with the purpose of separating aspects of domain modeling, presentation, navigation and adaptation. This separation allows the developer to address the construction of the HS following a divide-and-conquer approach, in a similar way to other models such as AHAM [6, 7], TANGOW [8] and LAOS [3, 9]. In addition, the model provides evolutionary mechanisms that automatically ensure the integrity of the changes that the developer makes during the construction of the HS and its subsequent maintenance [1]. And finally, the model supports four types of navigation that the user can choose according to his aim each time that he uses the system [2]. Each of these types of navigation adapts the HS taking into account different characteristics of the user (knowledge, preferences, experience, goals, etc.), stored in a user model.

So, the SEM-HP model gives the author three elements for the development of evolutionary AHS (Fig. 1): a development process, an architecture and an author tool. The *development process* establishes some guidelines to create the system from a standpoint of software engineering. The *architecture* describes the representation models used to capture each of the phases of the development process. And the *author tool*, called JSEM-HP, makes the creation of the system easier, according to the architecture and the development process that have been proposed in the model.

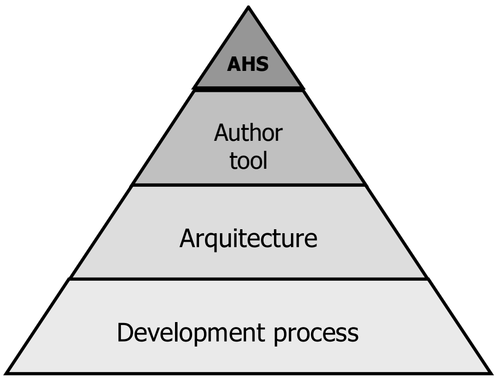

Fig. 1. SEM-HP Model

In spite of its special characteristics, the design and development of a HS is also a software development process. Because of this, the quality of the obtained product depends on the quality of the process carried out to obtain it. So, we think that applying a software engineering process to develop this kind of systems is necessary. The development process proposed in SEM-HP model (Fig. 2) is composed of four phases. These phases are inherent in the design of HS: memorization, presentation, navigation and learning. The completion of each phase produces as a result a subsystem of the architecture.

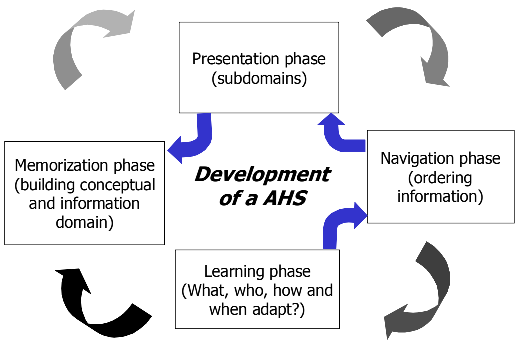

Fig. 2. SEM-HP Development Process

In the *memorization phase* the author models the information domain to be visited by the system users. In order to make the semantic relations between the information items explicit, the author also specifies the underlying conceptual domain. The conceptual domain is a set of concepts which can be used to classify the different information items offered in the HS. We understand as concept an idea, thought or abstraction that can be tagged by the authors in order to make explicit their knowledge about it and make it understandable. The conceptual domain also includes the set of semantic associations that can be established between the concepts. The information domain is the set of items that are associated to the concepts in the specific conceptual domain. An item is any piece of information that we can access in the HS (html pages or any kind of electronic resource).

In the *presentation phase* the author selects different presentations or views of the knowledge domain obtained in the previous phase. In the *navigation phase* the author establishes how the user can navigate the available information items. And, finally, in the *learning phase* the author solves aspects related to adaptation, answering questions such as ‘to what?’, ‘what?’, ‘how?’ and ‘when to adapt?’ As result, it establishes needed mechanisms for the system to be able to adjust to each user’s characteristics and interests while the system is functioning.

These phases are not sequential, but iterative. That is, the author can go back to an earlier phase when he needs it. In addition, this process involves an evolutionary development because its four phases are able to integrate changes that the author makes in the system's structure in an easy, flexible and consistent way.

3 SEM-HP Architecture

The architecture proposed by SEM-HP is structured in layers, performing a double division, as we can see in Fig. 3.

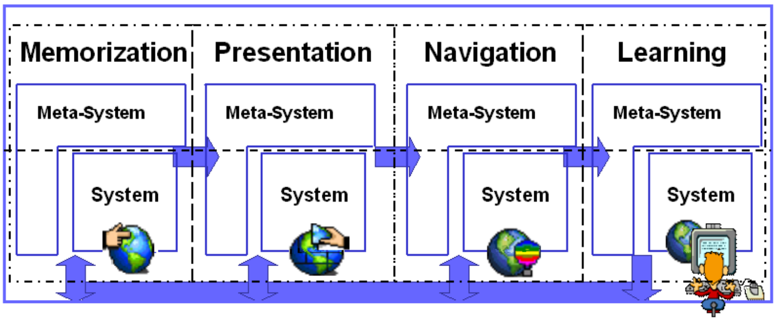

Fig. 3. SEM-HP Architecture

The *vertical division* considers four interrelated subsystems, which are interacting. These subsystems are called Memorization Subsystem, Presentation Subsystem, Navigation Subsystem and Learning Subsystem. Each of these systems stores some of the model’s characteristics and gives some functionality to the rest of the subsystems and to the users.

The *horizontal division* distinguishes two layers in each of the previous subsystems: system and meta-system. Each of the layers represents a different level of abstraction. The least abstract level (system) comprises the representation models defined by the author during the corresponding development phase, while the most abstract level (meta-system) includes the evolutionary mechanisms that will allow integrating and propagating the changes performed by the author in the elements of the corresponding subsystem. The evolutionary mechanisms included in the meta-system are: evolutionary actions, restrictions and change propagation.

The author interacts with the meta-system to build and modify the HS. To perform a change in a subsystem the author must choose the appropriate evolutionary action and run it. In order to assure the integrity of system, the meta-system denies inconsistent changes. So, an evolutionary action is only executed if it satisfies a set of restrictions imposed by the model (*system restrictions*) and by the author (*author restrictions*). Finally, modifying an element in one of the four subsystems can cause the need of updating other elements in the same system (*internal propagation*) or even in other subsystems (*external propagation*). Both of these kinds of propagation are carried out automatically in the model. In this way a coherent co-evolution of the whole architecture in the HS is guaranteed [1, 2]. For example, to remove a concept in the conceptual and information domain of the Memorization Subsystem requires delete the same concept in the views created in the Presentation Subsystem, and to delete all the associations that the concept had with items of information in both subsystems.

The *Memorization Subsystem* stores, structures and maintains the conceptual and informational domain of the HS. So, this subsystem is responsible for semantically structuring the knowledge domain, and to do this, it catalogues the information items on the underlying conceptual domain. The annotation of the information resources (often learning objects) permits automatically to handle the underlying semantics, thus improving the navigation and adaptation processes, as seen in [10].

The representation model used for describing both domains (conceptual and information) is a conceptual structure. The conceptual structure is a semantic net that includes two types of nodes semantically tagged to represent concepts and information items. A conceptual structure is formally defined as: CS = (C, I, Rc, Rf, Ac, Af), where C is a set of concepts, I is a set of information items, Rc is a set of conceptual relations, Rf is a set of functional relations, Ac is a set of conceptual associations and Af is a set of functional associations.

A *conceptual relation* $r_c \in Rc$ is the tag placed in the arc which links two concepts, $c_o \in C$ and $c_d \in C$, in the conceptual structure (is_a, is_composed_of, etc.). A *conceptual association* $a_c \in Ac$ is composed by two concepts and a conceptual relation r_c that exists between them $<c_o, r_c, c_d>$.

A *functional relation* $r_f \in Rf$ tags a link that joins an item, $i_j \in I$, to the associated concept, $c_k \in C$, and denotes the role or function that the information in the item performs regarding to the concept (definition, example, opinion, etc.). A *functional association* $a_f \in Af$ is composed of a concept, an item and the functional relation that exists between them $<c_k, r_f, i_j>$. In addition, each item has a set of properties which describes its information: author, media, language, date and level of difficulty, among others.

The Memorization Subsystem is comparable with the domain model of LAOS [9], but in LAOS the relationships among concepts are hierarchical while in our model, SEM-HP, the concepts are associated by means of a conceptual net. Regarding to the items of information, in our model these are directly associated to the concepts on the net while in LAOS the pieces of information are stored as attributes of the concepts. In both models the function or role of an item regarding to the associated concept (title, description, example, etc.) is explicitly represented; in SEM-HP by the tag of the functional association between the item and the concept and in LAOS using the type of the attributes associated to the concept.

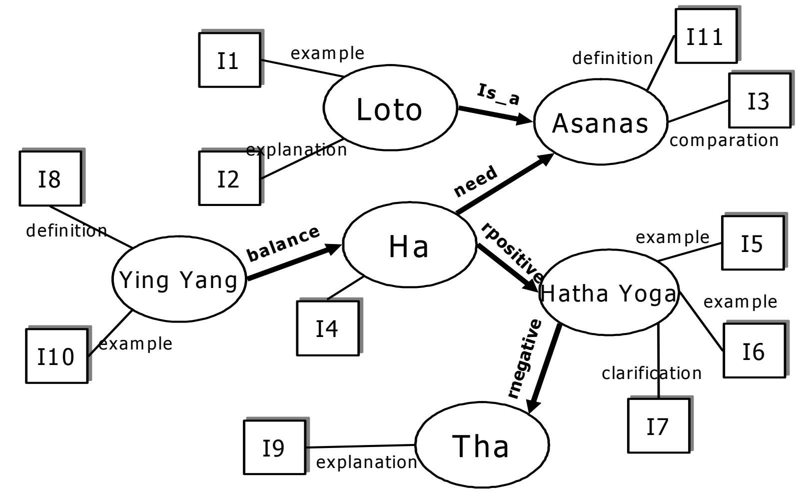

Fig. 4. Example of Conceptual Structure of Memorization

Fig. 4 shows a Conceptual Structure of Memorization (CS_M) in which the knowledge domain is a type of Yoga called “Hatha-Yoga”. In it, concepts are drawn as circles or ellipses, conceptual relations as arrows, information items are rectangles and functional relations are represented by lines. Obviously, it is an example and it is not the whole structure, so some concepts that could be in the CS_M have not been represented.

The evolutionary approach of SEM-HP allows the author to extend, reduce or update the CS_M at any time. To do this, there is a set of evolutionary actions that allows creating, updating and deleting a concept, an item, a functional association or a conceptual association. For example, if the author deletes the concept “Ying Yang”, the meta-system automatically deletes the conceptual association “balance” and the functional associations “definition” (between I8 with “Ying Yang”) and “example” (between I10 with “Ying Yang”). The items I8 and I10 are still available in a central repository if the author considers that it is necessary. In addition, the meta-system executes an automatic propagation mechanism in the following subsystems.

In the ***Presentation Subsystem*** each presentation of the whole conceptual and information domain is called Conceptual Structure of Presentation (CS_P). A CS_P has a subset of concepts, items, functional associations and conceptual associations included in the CS_M. Each presentation updates the modifications performed in the Memorization Subsystem. In the previous example, the meta-system would propagate the needed changes in all the presentations containing the concept “Ying Yang”.

The *Navigation Subsystem* defines a set of order rules (Ro) which establish a partial order to navigate in each CS_P. This order is based on: 1) the last information item accessed by the user, 2) the concept to which this item is associated, and 3) the concepts to which it is possible to get from the current concept, following a conceptual relationship. So, for example, if the last visited item in Fig. 4 is I4 associated to the concept “Ha”, then the user can visit any item associated to the concept “Asanas” (I11, I3) or to the concept “Hatha-Yoga” (I5, I6, I7). When a concept or an item is deleted in the CS_P, the meta-system propagates the change to all the Ro that contains that concept or item. This propagation implies to remove complete rules or some predicates in the rules. This propagation is applied in a similar way to the rules in the learning subsystem.

The *Learning Subsystem* models the user and adapts the structure and operation of the HS to his personal characteristics. The information included in the user model is very diverse: personal data, knowledge state composed of the user knowledge grade about each item of the HS ("null", "low", "medium", "high", "total"), experience on the subject, navigation experience, preferences, interests and goals. To carry out the adaptation process, the Learning Subsystem applies a set of techniques and adaptive methods which are based on rules predefined by the author, among others:

- *Update rules* (Ru): Increase the user knowledge degree on the items of information that the user visits (reads). The default update rule for an item i_j, Ru (i_j) implies that the user fully knows the item after visits it ("total" knowledge degree about i_j). However, the author can modify the update rule for an item, expressing another type of update on the visited item (for example, an increase over the degree of knowledge that he has now about the item) and even updates on other related items. The format of these rules is if-then, like in AHAM [6], but in this case there are several differences: In SEM-HP, update rules are applied only for items (atomic concepts in AHAM) but the knowledge about concepts (abstract concepts in AHAM) is calculated by using Weigh Rules; SEM-HP never performs a automatic negative update when an user reads an item; in SEM-HP, the author can specify that an update is only executed if it is the first time the user visits the item; and finally, in SEM-HP, the update rules are not executed recursively in order to avoid cycles.
- *Weigh rules* (Rw): Each weigh rule calculates the user's knowledge about a concept. To do it, it uses the user's knowledge about each of the items related to this concept. The knowledge about each item is pondered with a weigh establish by the author according to how important this item is for learning the concept.
- *Knowledge Rules* (Rk): Determine which items the user can visit (accessible items) and which not at a particular time. Moreover, they establish which of the accessible items have relevant information depending on the current user knowledge state. So, each knowledge rule Rk(i_j) defines the minimum knowledge that the user should have about a determined set of items in order to access i_j (accessibility restrictions), and/or the maximum knowledge that the user should have about other specific items to highlight the visit of i_j (idoneity restrictions). For example, the author could establish that I11 in Fig. 4 can be accessed only if the user has at least a degree of knowledge "medium" about I2 and I4. The author can define several Rk for the same item, one for every possible way of being properly prepared to learn it (the user just has to satisfy one). Again, the Rk have points in common with the adaptation rules in AHAM [6]. However, in SEM-HP the pedagogical requirements needed to visit the items of information are specified outside the domain model. This allows the author to create several rules of knowledge for the same item, so that the user can follow the path of their choice.

Most of the adaptations performed in SEM-HP are designed to customize the navigation of the user. The user browses directly on the semantic network, which allows users to have a view of the context of navigation at any time. The update and knowledge rules permit a navigation restricted by knowledge, that is, the user can only access the contents of an item if has the required knowledge to do it. Thus, the item selection over the semantic net will open it in the browser (or the suitable application) if the user satisfies any knowledge rule associated to the item. However, other three navigation modes are supported in SEM-HP [2]: free navigation (without restrictions), navigation restricted by order rules and navigation by concepts (the user clicks concepts on the semantic net and obtains a personalized summary of the information associated to the selected concept).

4 Results and Further Work

In order to assess our model, we have carried out a semi-formal evaluation with 31 students from the University of Granada. We have used JSEM-HP to create a hypermedia system whose knowledge domain was the Object Oriented Programming (course taken by these students). The evaluation was successful in the 35 aspects tested about the tool JSEM-HP. This evaluation was made by using an opinion questionnaire that students made after using the system to learn the general concepts of Object-Oriented Programming. For example, the students gave an average score of 4.29 points (maximum 5) on the usefulness of the graphic browser of JSEM-HP (in the SEM-HP model the navigation is performed on the semantic net itself), 4.06 points on the usefulness of navigation on a partial view of the graph (the SEM-HP model provides the user with a different presentation -CS_P- depending on the knowledge subdomain in which the user is more interested) and 4.16 points in adaptation. Questions were also asked to compare JSEM-HP browsing and traditional web browsing. In this aspect, students were 3.8 points on the

efficiency of finding information through the browser on JSEM-HP against seeking information on the Web.
Our immediate further work is focused on finishing the development of JSEM-HP in order to carry out a wider assessment of the tool, both from a user perspective (navigation and adaptation) and from an author perspective (design, construction and maintenance).

5 Conclusions

SEM-HP is a systemic, semantic and evolutionary model to develop adaptive and evolutionary hypermedia systems. This model guarantees a semantic correspondence between structure and functionality in the system. Therefore, the model supports the author in the development and maintenance processes.

Specifically, SEM-HP model gives the author three elements for the development of evolutionary Adaptive Hypermedia Systems: a systematic development process, a layered architecture and an author tool which permits to construct and navigate AHS according to the development process and the architecture proposed. The architecture of each developed AHS is divided in four subsystems: modeling, presentation, navigation and adaptation. In addition, there are two abstraction levels in each subsystem to perform an automatic evolution and co-evolution.

Another differentiating aspect of SEM-HP is that the navigation structure displays, in addition to information items, the concepts they describe and the relations between them. Furthermore, directly on the navigation structure, the users can check their degree of knowledge about the items and concepts offered. Thus the semantics provided by the author during construction of the system (CS_M, CS_P, Ro, Ru, Rw, Rk) arises during user navigation, which would improve the process of adaptation and the control that the user has over it.

Acknowledgments. This research is supported by the Spanish MCYT under R+D projects TIN2008-06596-C02-02, TIN2007-64718 and TIN2007-60199, by the Research Program of the Andalusian Government under project P08-TIC-03717 and by the European Regional Development Fund (ERDF).

References

1. García-Cabrera, L., Rodríguez, MªJ. and Parets, J.: 2002, ‘Evolving Hypermedia Systems: a Layered Software Architecture’. *Journal of Software Maintenance and Evolution: Research and Practice*. John Wiley & Sons, Ltd. Vol. **14** (5). Pp: 389-405.
2. Medina-Medina, N., Molina-Ortiz, F. and García-Cabrera, L.: 2005, ‘Diversity of Structures and Adaptive Methods on an Evolutionary Hypermedia System’. *Journal IEE Proc.-Software*. Vol.: **152** (3). Pp. 119-126.
3. Cristea, A., Stewart, C., Sirmakessis, S.: 2006. ‘Towards More Efficient Generic Semantic Authoring for Adaptive Hypermedia’. *Proceedings of the Joint International Workshop on Adaptivity, Personalization & the Semantic Web, AH’2004*. Pp: 11-20.
4. Conlan, O., Lewis, D., Higel, S., O’Sullivan, D. and Wade, V.: 2003. ‘Applying Adaptive Hypermedia Techniques to Semantic Web Service Composition’. *Proceedings of the International Workshop on Adaptive Hypermedia and Adaptive Web-based Systems (AH 2003)*. Pp: 53-62.
5. Frasincar, F. and Houben, G.: 2002. ‘Hypermedia Presentation Adaptation on the Semantic Web’. *Proccedings of the 2nd International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems (AH 2002)*. Pp: 133-142.
6. De Bra, P., Aerts, A., Smits, D., and Stash, N. : 2002. ‘AHA! meets AHAM’. *Proceedings of the 2nd International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems*, Pp: 381-384.
7. De Bra, P., Aroyo, L. and Cristea, A.: 2004, ‘Adaptive Web-Based Educational Hypermedia’. *Proceedings of the 3rd Web Dynamics.* Pp: 387–410.
8. Carro, R. M., Pulido, E., and Rodrígues, P.: 1999. ‘TANGOW: Task-based Adaptive learNer Guidance on the WWW’. *Computer Science Report, Eindhoven University of Technology*. Pp: 49–57.
9. Cristea, A. and De Mooij, A.: 2003. ‘LAOS: Layered WWW AHS Authoring Model and their corresponding Algebraic Operators’. *Proceedings of the WWW 2003 Conference*, ACM, retrieved March 16, 2006 from http://www2003.org/cdrom/papers/alternate/P301/p301-cristea.pdf.
10. Dolog, P., Henze, N., Nejdl, W. and Sintek, M.: 2004. ‘The Personal Reader: Personalizing and Enriching Learning Resources Using Semantic Web Technologies’. *Proceedings of the 3rd International Conference, AH 2004*. Pp: 85–94.