Evolution in Adaptive Hypermedia Systems[1]

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ABSTRACT
In this paper, the need of mechanisms of evolution in adaptive hypermedia systems is argued. Moreover, the basic characteristics of these systems are described and the user adaptation carried out in them is situated in the context of evolution models. Finally, SEM-HP, an evolutionary and adaptive hypermedia system, is presented and outlined.

Keywords
Hypermedia System, User Adaptation, Models of Evolution

1. INTRODUCTION
A Software System (SS) is a set of processors, which interact between them and with the environment, in such a way that the whole SS could be seen, from a functional perspective, as a sole processor [14,15,16]. The modeller performs changes in the SS during its development process, but also later, during its functional life. These last changes modify the structure or functionality of the SS in order to produce adaptations, which guarantee the usefulness of the interaction of the SS with its environment. Therefore, the qualification of a Software System for evolution implies to anticipate what are the kinds of modifications that the SS could suffer while its development and functioning. Thus, the developer could, in the future, perform the necessary changes (structural or functional) in the SS and adapt it to the environment in an easy and flexible way.

An adaptive hypermedia system (AHS) is a Software System, which structures information in such way that is possible to read its documents in a no linear order and which is able to adjust the presented information to certain user features; facilitating the navigation and comprehension of the offered material. The amount of research in the area of adaptive hypermedia systems (AHSs) is considerable, and contemplating the obtained results seems evident that the adaptation realized by these systems increases the usability of the traditional hypermedia systems.

Since evolution is a more wide process than adaptation to the user differences, the aim of this paper is not to discuss the utility of AHSs, but provide a conceptual view of user adaptation in the context of software evolution. Because of that, we consider that adaptation in AHSs must be completed using evolution mechanisms, which allow updating and modification of the AHS, in accordance with the transformations happened in the environment.

User adaptation performed in adaptive hypermedia systems is described in section 2. Section 3 details different ways, mechanisms and models of evolution and situates user adaptation in context. Section 4 describes more specifically, how user adaptation is carried out in SEM-HP, our evolutionary and adaptive hypermedia system. Finally, conclusions and further work are considered.

2. ADAPTATION IN AHSs
Adaptive hypermedia systems attempt to adapt presentation of hyperdocuments and the structure of links to the level of knowledge, preferences and interests of the user. Then, fitting information and navigation to the features of each user, comprehension and disorientation problems are reduced in AHSs.

Most of current adaptive hypermedia systems adapt to each user [1,3,6,7,8,12,13,18,20], however, AHSs which adapt to an user group exist. For instance, in the approach proposed by Bollen [4], an user can benefit of previous navigation realized by other users, using techniques that adapt the structure of links towards the common browsing patterns of the user group. Other example is INTRIGUE [2] an adaptive hypermedia system which suggests the travel that better fits the distribution of a group of tourists.

Some AHSs that adapt to individual users take into account the user context [1,13]: work organization, physical localization, etc. Other AHSs, as the proposed by Bailey et al. [3], also consider the spatial context, that is to say, they perform adaptation taking into account the user navigation path through hyperspace before reaching the present page.

In any case, the capacity of adaptation of an adaptive hypermedia system depends on the characteristics of the user which it considers (the user model) and the methods and techniques of adaptation that it applies.

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2.1 User Model

The user model (UM) represents and stores the user features, which will be considered in adaptation. Obviously, a better representation of the user characteristics implies greatest and best possibilities of adaptation. The UM is usually initialized using stereotypes, and the main difficulty derives from the automatic update during user browsing; therefore only those characteristics which the AHS is able of updating automatically can be included in the UM.

With regard to the manner of representing of user model, very diverse alternatives are found in scientific literature. For example, in AHA [20] the UM is represented as a table, in which each concept has associated a list of pairs attribute/value, in ATS [18] the UM is a probabilistic and episodic model, in KBS Hyperbook [12] is a bayesian model, etc. In our proposal, SEM-HP [11], the user model is represented using a Petri Net.

Anyway, the capacity of adaptation depends more on what are the user features represented in the UM that on how these are represented. Table 1 describes the characteristics more frequently included in the user model.

Table 1. User Model

Feature	Description
Goal	Information that the user desires to know.
Knowledge	Level of knowledge of the user about each document offered by the AHS.
Read	Documents read by the user.
Ready to read	Documents that can be read by the user.
Subject experience	General knowledge of the user about the conceptual domain of the AHS.
Hyperspace experience	Practice of the user in the use of hypermedia systems.
Preferences	Predilections and tastes of the user.
Personal data	Data such as name, age, sex, profession, etc. This information is used in stereotypes.

2.2 Adaptive Methods and Techniques

Since a hypermedia system is a set of hyperdocuments connected by means of links, two aspects can be adapted: the structure of links and the information contained in the hyperdocuments. Adaptation of the link structure is named *adaptive navigation* and adaptation of the pages is named *adaptive presentation*. Brusilovsky in [5] provides a full description of the adaptive methods utilized in AHSs.

2.2.1 Adaptive Navigation

These methods try to achieve three main objectives: a) To offer personalized views of the same link structure, b) To provide orientation support, they assist the user in avoiding to be lost in the hyperspace and c) To guide the user during his navigation in order to obtain the desired information in an optimum way.

These methods use adaptive techniques such as link disabling (to remove functioning of the link), link hiding, link annotation (augmenting the link with textual or visual information concerning the destination page) or sorting of links.

2.2.2 Adaptive Presentation

Presentation of pages can be adapted to the user including additional information that the user needs, or deleting information that the user already knows. Other adaptive presentation methods imply reordering the information of the page depending on the user features or the use of different versions of the same information in function of the reader. The information contained in the versions is the same but with distinct level of specialization, idiom, media, etc.

These techniques split the page into fragments and each fragment can be optionally shown in the current presentation; in the affirmative case what version of the fragment is included and in what position into the page is determined. Decisions are taken based on the characteristics of the user.

3. EVOLUTION ⊃ ADAPTATION

In the evolutionary process of a Software System, the developer is a very important element, since, the developer is in charge of modeling and designing the capacity of evolution of SS and, after that, he carries out evolutionary actions in order to produce the necessary changes over the system. However, the developer is not the unique element that must be considered. Figure 1 shows the abstract structure of interaction proposed in [14] which represents the essential elements in the evolution of a SS.

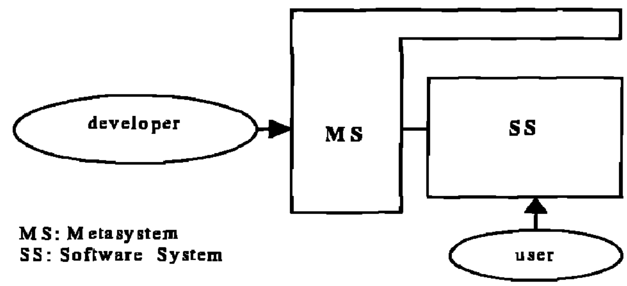

Figure 1. Interaction Structure.

- The *developer* resolves what modifications will be carried out over the SS.
- The *Metasystem* conducts the interaction between the SS and the developer.
- The *Software System* suffers the changes.
- The *user* utilizes the SS.

From a general perspective, the Software Systems can evolve in two unlike ways. Although the developer is involved in both, the difference between them depends on the intervention is direct or indirect.

1. Evolution of the SS driven by the developer.
2. Self-evolution of the SS.

The first type of evolution implies a direct intervention of the developer, in such a way that he is who drives the changes in the SS. The second type is performed in an automatic way depending on certain mechanisms defined previously by the developer; therefore, his intervention in this second case is indirect.

User adaptation carried out in adaptive hypermedia systems is performed automatically during the user navigation; thus, the modeller does not intervene in a direct way on the adaptation. Not even the user solicits explicitly the adaptation, since in that case, the hypermedia system is *adaptable* instead of *adaptive*. Consequently, the adaptation of AHSs is included in the second kind of evolution. The mechanisms defined earlier by the developer, in order to attain the self-adaptation of the AHS, are the user model and the adaptive methods explained in subsections 2.1 and 2.2 respectively. As well, the update rules defined by the developer for updating the UM during navigation are part of these mechanisms.

With the aim of situating more exactly the adaptation of AHSs in the context of evolution, mechanisms and models of evolution are described following [19] in next subsections.

3.1 Mechanisms of Evolution

The mechanisms of evolution represent distinct modes used by a SS for changing. Each mechanism includes a set of activities, such that their coordinate execution makes the change. In [19], two kinds of mechanisms are proposed: Adaptation and Heredity.

3.1.1 Adaptation

As in biology, adaptation is based on the need of adjusting, learning or mutating the system in accordance with requirements of the environment. Adaptation can imply changes of structure or changes of functioning in a SS; depending on the performed modification two kinds of adaptations are distinguished:

- Adaptation by Accommodation/Learning.

The system adapts to its environment, learning the best mode of using its structure but without modifying it. This type of adaptation is carried out in functional environments, where the user communicates with the SS using actions of its interface and perceives the adaptation as changes in the answers of the system.

- Adaptation by Mutation/Differentiation.

This type of adaptation is more radical that the former type, because it implies changes in the structure of the SS. Modifications in the structure of the SS cause changes in the functional character of the system, but also introduce new possibilities of adaptation by accommodation/learning. These modifications of the SS need the intervention of the Metasystem.

3.1.2 Heredity

The heredity mechanism is used in generating descendent Software Systems, which inherit the adaptations from their fathers. That is to say, the new SS inherits the initial structure and the changes performed over the structure as consequence of the two types of adaptation explained in the previous subsection.

The environment of an AHS is a functional environment, since the user browses, accesses and reads hyperdocuments using the navigation interface that the AHS offers to him. In AHSs, ***adaptive navigation techniques*** alter the use of the link structure: hiding, annotating, disabling or reordering the links. ***Adaptive presentation techniques*** solely show or hide fragments of the pages. As a result of the nature of these techniques, the adaptive methods that use them do not imply structural changes. Therefore, the AHS adapts to the user modifying the way of use of its structure, but without changing it. Moreover, none of the AHSs reviewed in the scientific literature incorporates the concept of Metasystem neither anything similar that allows to make modifications in its structure. As a consequence of this analysis, seems reasonable to include user adaptation carried out by the adaptive hypermedia systems into the mechanism of adaptation by accommodation/learning.

3.2 Models of Evolution

Following [19], a model of evolution is a symbolic representation of a particular mean of effecting changes in a SS. Every model makes use of one of the evolutionary mechanisms described in the previous subsection. Six different models of evolution can be distinguished:

1. Modeller Driven Meta-Teleology.

The modeller carries out modifications in the structure of the Metasystem using actions of its evolution interface. This model applies the mechanism of adaptation by mutation/differentiation.

2. Modeller Driven Teleology.

Changes in the structure of the Software System are produced by the modeller using actions of the action interface of the Metasystem. The mechanism of adaptation by mutation/ differentiation is applied.

3. Inheritance of the Acquired Meta-Characters.

If the modeller takes the initiative, a new Metasystem (son) can be generated from an old Metasystem (father). The obtained Metasystem inherits the meta-characters acquired by the father during its evolution. This model applies heredity mechanism.

4. Inheritance of the Acquired Characters.

This model is followed by the modeller when he wants to create a new Software System from an existing SS. The generated SS inherits the new characteristics that the old SS acquired while its evolution. This model utilizes the heredity mechanism.

5. Metasystem-SS Self-Adaptation.

The Metasystem performs structural changes in the SS, without any direct intervention of the modeller. This model applies the mechanism of adaptation by mutation/differentiation.

6. System Self-Adaptation.

The SS executes an adaptive process without that the modeller neither the Metasystem take part actively in that process. This model applies the mechanism of adaptation by accommodation/learning.

Figure 2 superimposes the six models of evolution over the interaction structure of figure 1. Each arrow has associated the number of the model of evolution represented.

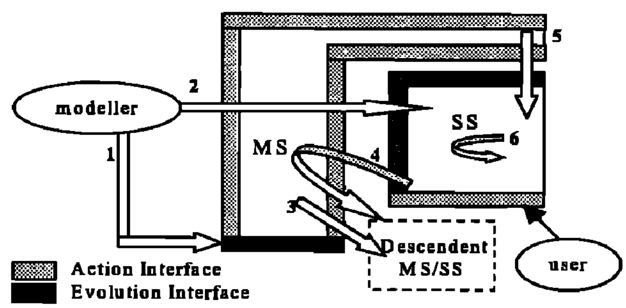

Figure 2. Models of Evolution.

An AHS carries out the process of user adaptation during the user browses information, without direct intervention of the modeller. In addition, as justified in subsection 3.1, these systems apply mechanisms of adaptation by accommodation/learning. Therefore, AHSs fit perfectly in the sixth model of evolution.

4. SEM-HP: AN EVOLUTIONARY AND ADAPTIVE HYPERMEDIA SYSTEM

In previous sections has been argued that user adaptation performed in current adaptive hypermedia systems follows a particular model of evolution: *System Self-Adaptation*. Hence, that evolution is a process more complete than merely user adaptation of the AHSs is confirmed. The evolution of a hypermedia system includes user adaptation: *Evolutionary HS ⊃ Adaptive HS.*

The motivation of our proposal is to provide a whole capacity of evolution for hypermedia systems, facilitating to the author a set of evolutionary actions whose utilization allows him to perform changes in the AHS, during and after its construction, in a simple and flexible way. Then, both user and author (developer) benefit of evolution.

The SEM-HP model [9,10,11] permits the development of evolutionary hypermedia systems (EHS) by means of a development process divided in four phases and explained in [11]. The obtained systems offer the knowledge captured by their authors, so they change very frequently. For this reason, SEM-HP provides a set of evolutionary actions (AC_e); the author utilizes one or other depending of the needed modifications. The consistency of the system must be guaranteed at any moment, therefore an AC_e only is executed if it satisfies the whole set of restrictions defined in the system. The set of restrictions is not static, because the author can modify, add or delete restrictions, using a special set of AC_e, whose restrictions are Metarestrictions.

The SEM-HP model conceives an EHS as composed by four interrelated and interacting subsystems. The three first subsystems are described in [17] and provide evolutionary capacities. The fourth subsystem, which involves the adaptive features and its further evolution, will be described here in more detail.

- Memorization Subsystem.

It is in charge of the storage, structuring and maintenance of the knowledge offered by the system. The main element in this subsystem is the Conceptual Structure (CS). The CS is a semantic net with two types of nodes: concepts and items. Concepts are ideas labeled semantically. Items are pieces of information which deal with the concepts, i.e. documents offered by the system. Also, there are two types of relations in the CS: relations among concepts and relations among concepts and items. Concepts, items or relations can be created, deleted or modified by the author using the AC_e (if the result is consistent).

- Presentation Subsystem.

This subsystem allows us to select a subset of the CS created and stored in the memorization subsystem. In this case, the evolutionary actions are destined for hiding or showing concepts, items or relations of the original CS.

- Navigation Subsystem.

This subsystem permits the author to add new order restrictions over the CS obtained in the presentation subsystem. These restrictions are expressed in temporal logic and they establish a partial order among items. A Petri Net is constructed automatically from the order restrictions and the CS. The Petri Net is an operational formalism, which provides the possibility of following the tracks of the user during his navigation. In this subsystem, order restrictions can be deleted, modified or extended by the author using AC_e., as long as the result of those modifications is consistent.

- Learning Subsystem.

It is in charge of carrying out user adaptation as proposed in adaptive hypermedia systems. In order to it, the learning subsystem stores and updates an user model and, based on this UM, applies adaptive methods over the structure of navigation, which is no other than the conceptual structure. Adaptive methods do not modify the selfsame CS, but allow modifications on the use of the CS depending on the user (user navigation).

The user features included in the UM can be divided into two groups: a) *Variable characteristics* which change frequently during navigation b) *Stable characteristics* which do not change often. Variable characteristics include information concerning the level of user knowledge about each item, the items that the user has read, reading number of each item and reachable items that the user is ready to read. Variable characteristics are represented and updated over the Petri Net:

- Each item has associated the *level of knowledge* that the user has about it. The level of knowledge is represented with a number between zero and a hundred.
- Order restrictions created in the navigation subsystem are transformed into knowledge restrictions by the author. These new restrictions are named *knowledge rules*. For every item exists a knowledge rule, which determinates what items must be previously known by the user and what is the level of knowledge needed in order to reach the item.
- The author adds a set of *update rules*. Each item has associated an update rule, which is executed whenever the item is visited by the user. The update rule implies a variation in the level of user knowledge about the visited item, but can also modify the level of user knowledge about other items.

Adaptive methods utilized in SEM-HP hide and disable over the CS of navigation those items whose knowledge restrictions are not satisfied, then, the user has not access to them. The remaining items are annotated with the number of visits and the level of knowledge of the user.

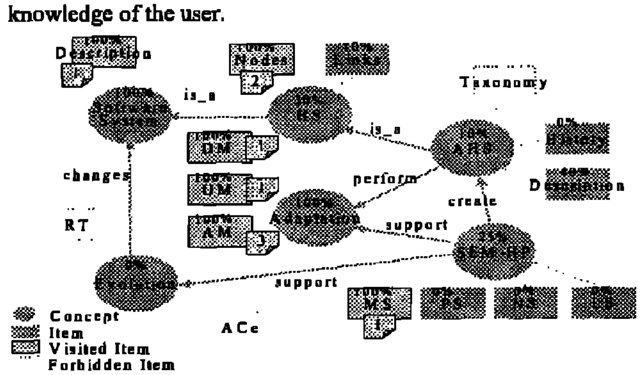

Figure 3. Example of an Adaptive CS.

The AC_e provided by SEM-HP allow the author to modify the *knowledge rules* and *update rules*, as long as, it does not originate a lack of consistency in the learning subsystem. Evidently, those changes modify the adaptive behavior of the hypermedia system, however this adaptation is not produced automatically by the system following the sixth model of evolution (user adaptation typical of the AHSs), but that is performed in a direct way by the modeller according to the second model of evolution.

Is possible that to modify an element in some of the four described subsystem generates the need of to carry out modifications over other elements of the self subsystem (internal propagation of changes) or even, over elements of the other subsystems (external propagation of changes). In SEM-HP, for both situations exists automatic support, which facilitates the task of the authors and preserves the consistency of the system.

Figure 4 sums up the architecture of SEM-HP, it displays the four interrelated subsystems and the generic structure of each subsystem. In addition, both the evolutionary process and the user adaptation are considered in the figure.

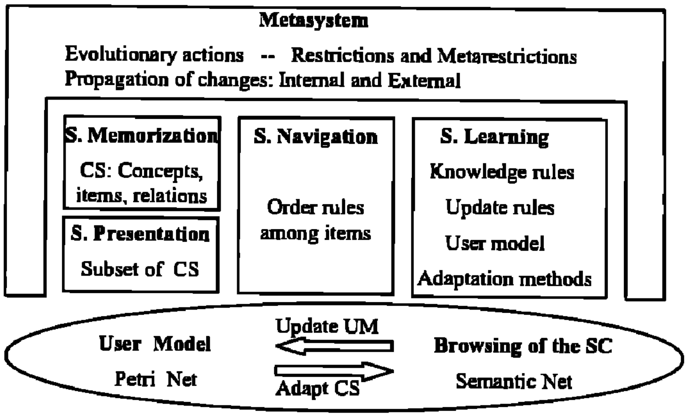

Figure 4. SEM-HP model.

5. CONCLUSIONS AND FURTHER WORK

Evolution and user adaptation are different concepts. However, the intersection between them is not empty, since user adaptation is a subtype of evolution. Specifically, user adaptation follows a model of evolution, which applies the mechanism of adaptation by accommodation/learning. User adaptation modifies the user navigation depending on its concrete features, but does not realize structural changes in the system. In this way, functional changes are carried out without requiring direct intervention of the developer, using adaptive methods defined previously by him.

Our efforts are directed to achieve a hypermedia system with total capacity of evolution, that is to say, an EHS that supports the six evolution models. At present, we are working in two main tasks: On the one hand, we want to define a whole set of AC_e that permits us to evolve the learning subsystem (these AC_e already have been defined and formalized for the rest of subsystem [11]) and on the other hand, we will try to complete the user adaptation carried out in this subsystem, introducing additional user features, such as goals and levels of subject experience.

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