systems, we have chosen 10 AHES from different domains of intervention. We will compare each one of them based on some well-defined metrics to define a proper path to construct and initialize a learner model using a combination of methods/model.

- ***AHA!,*** the "Adaptive Hypermedia Architecture", was originally developed to support an on-line course with some user guidance through conditional (extra) explanations and conditional link hiding. It consists of a set of concepts, some of which are linked to pages or objects (or fragments). Concepts can be used to represent topics of the application domain [5].

- The ***ADAPTWEB*** environment is an adaptive hypermedia system providing the same content adapted to different students' groups. ADAPTWEB is an open source environment in operation in different universities [6].

- ***AVANTI*** is a system designed for a range of users with different needs. This system combines in the stages of data collection and initialization of the learner model stereotypes and superposition method to create initial assumptions, and to maintain the knowledge of the user [7].

- ***ANATOM-TUTOR*** Developed for teaching anatomy of the brain at university level, ANATOM-TUTOR's hypertext component makes use of a user model to adapt hypertext lessons at both the link and the text level. Hypertext is one of three learning modes offered by ANATOM-TUTOR [8].

- The ***AHM*** system, in which the adaptation depends on the level of expertise on the concepts of the field know the system is a subset of all the user's domain concepts [9].

- The ***ELM-ART*** system is an Adaptive distance Tutor system, which support learning Lisp programming language. It uses different techniques for initializing and updating its learning model: overlay model, the complex machine learning methods and Bayesian networks to represent episodic learning model [10].

- ***INSPIRE*** is an adaptive hypermedia that emphasizes the fact that learners perceive and process information in very different ways and integrates ideas from theories of instructional design and learning styles. INSPIRE, throughout its interaction with the learner, dynamically generates learner-tailored lessons that gradually lead to the accomplishment of learner's learning goals [11].

- In ***HYPERADAPT***, a specialized approach utilizing an aspect-oriented programming is used. This hypermedia places the adaptivity into separate modules called adaptation aspects. The aspects are not applied on a model level, but on XML documents [12].

- ***HYNECOS*** is adaptive hypermedia that demonstrates the applicability of the Hypertext Design Model HDM for design of hypertext-based information systems from relational databases. HYNECOS contains textual and graphical data about patients (administrative data, reports, x-rays etc.), hospital staff (names, telephones and shift-information about all staff members), a medical encyclopedia (diseases, treatments, and prognosis) and the location of the wards (room-plans, beds, occupancy etc.) [13].

- The ***METADOC*** system is an adaptive hypermedia mainly used in medicine, it's not only has hypertext capabilities but also has knowledge about the documents it represents. This knowledge enables the document to modify its level of presentation to suit the user. METADOC builds and dynamically maintains a user model for each reader [14].

2.3. The functionalities of a learner model in existing AHES

The intelligence of an AHES is mainly attributed to its ability to adapt to a specific learner during the teaching process; adaptation depends on the individual learner's knowledge of the subject taught and other relevant characteristics of the learner; relevant knowledge and information of the learner is often managed in a learner model [15], [16], [17].

The learner model category plays an important role in the implementation of intelligence and personalization of AHES. Specifically, a learner model can help personalize learning, assess learner knowledge, track learner progress, etc.

In Table 1, we identified six essential functionalities of a learner model: Personalizing learning, assessment of the learner's knowledge, follow-up and presentation of progress and actions of the learner, search for appropriate peers to get help, management of the learner information and automatic construction of exercises. And we will compare the existence of these functionalities in the AHES we took into our comparative study.

According to this table, we can conclude that two features are very common. Systems provide personalized learning by adapting teaching to the needs of the learner, giving relevant advice. Planning own learning activities, etc. Appropriate exams or tests are built according to the learner's performance.

Table 1. Comparative table between the functionalities of a learner model in existing AHES

The functionalities of a learner model	AHA	ADAPTWEB	AVANTI	ANATOMTUTOR	AHM	INSPIRE	HYPADAPTER	ELM-ART	HYNECOS	METADOC
Personalizing learning	X	-	X	X	X	X	-	X	-	-
Adaptation of teaching	X	X	X	-	-	-	-	-	-	-
Adapted presentation of teaching materials	X	-	-	X	-	X	-	-	-	-
Planning and organization of activities or educational contents	-	-	-	X	-	X	-	-	-	-
Selection of relevant teaching methods / strategies	-	-	X	-	-	-	-	X	-	-
Personalized help / advice	-	-	-	-	-	-	-	X	X	X
Adaptive assessment	-	X	-	-	X	-	-	-	-	-
Planning learning activities	X	-	X	-	-	-	-	-	-	-
Adaptive navigation	X	X	-	-	-	-	X	X	-	-
Assessment of the learner's knowledge	-	-	-	X	X	-	-	-	X	X
Analyzes of learner responses / beliefs	X	-	X	-	X	-	-	-	-	-
Diagnosing the mistakes of the learner	-	-	X	X	X	-	-	-	-	-
Planning the diagnostic dialogue	-	-	X		X	X	-	-	-	-
Adaptive explanations	X	-		X	-	-	-	-	-	-
Resolving ambiguities of error explanations	X	-	X	-	-	-	-	-	-	-
Follow-up and/or presentation of progress and actions of the learner	-	X	-	-	-	-	X	-	X	-
Search for appropriate peers to get help	-		-	-	X	-	-	-	X	-
Management of the learner information	-	X	-	-	X	-	X	-	X	X
Automatic construction of exercises	-	X	-	-	X	-	X		X	X

In addition, adaptive navigation has long been a technique used to achieve adaptation of learning. More specifically, to adapt teaching, teaching materials can be presented according to the level of knowledge and according to the learner's personal preference. Educational planning can also be organized according to the learner's knowledge, psychological characteristics or preferences. Pedagogical strategies can be selected according to the psychological characteristics and the learner's performance.

Learner model is also an essential component in assessing the learner's knowledge. For example, learner responses can be analyzed to infer beliefs, in other words, correct, erroneous, or incomplete knowledge. We can diagnose errors or misunderstandings of the learner according to the frequent mistakes of this learner and those of many students. Information on these errors is maintained in the learner model. Students' knowledge can be accessed from a conversation between the system and the learner. This diagnostic dialogue can be planned according to the learner's beliefs. From the results of the diagnosis, the explanations of the errors are adapted to each student according to his. In some cases, when there are ambiguities about the explanations, the learner's error history can be consulted to determine the appropriate explanations.

The other functionalities are also important and interesting even if they are present in few systems, for example: the monitoring of the progress of the learner, the automatic construction of exercises, etc. The presentation and comparison of the student's progress encourages the student to become more active. The automatic (or semi-automatic) construction of exercises allows tutors to increase their effectiveness. Peer research is very useful in collaborative models.

The majority of systems have two or more features at the same time, especially the two essential features of personalization of learning and assessment of learner knowledge, for example, AHM, AHA!, ANATOM-TUTOR, etc. Some systems focus on a single feature, which presents a mechanism for representing and maintaining the learner's actions by noting temporal aspects, in order to provide the learner with an overview of his or her model (long-term and short-term). This feature is important for getting relevant learner information and can be useful for other features, including learning adaptation and ambiguities resolution in diagnosing learner errors or misunderstandings.

2.4. The composition of a Learner model in existing AHES

Based on the survey we have presented in our previous work [20], we could resume the composition of learner models in different AHES into four major categories: characteristics of the learner, learning state, Learner Knowledge and Interactions between the system and the learner. [18]

- ***Characteristics of the learner:*** This category includes the learner's general or psychological characteristics, such as his or her learning purpose, type of learning, learning style preferences, computer experiences, level of learning concentration, the desired level of detail, availability, etc. The level of concentration could be inferred according to its interactions with the system, for example the time it is no longer active in the system. From this information, we can specify the anticipated needs of the learner.
- ***Learning state:*** Current or past states are classified in this category. More specifically, this type of model

contains the learning plan, the program followed, the learning history, etc. This information is then used to analyze and maintain the learner's situation.

- ***Interactions between the system and the learner:*** This is one of the key categories of learner information. Interactions between the system and the learner are recorded and updated. At the appropriate time, the system infers the learner's knowledge or learning status according to the recorded data. These interactions can be divided into two sub-categories: system visits and answers to questions. Visits include visits to educational content, such as the number of visits to the same unit, the duration of the same visit, the type of content, etc. The number of examples or aids requested is also recorded. Then the answers include the correct answers and the wrong answers. In fact, the system does not keep the answers; instead it records the corresponding parameters, for example the number of errors, the frequency of a particular error, the more frequent errors, the number of tests, etc.
- ***Learner Knowledge:*** This is another important category. The data or information in the previous categories is used to infer the learner's knowledge to provide a personalized learning. In this category, there may be the learner's level of knowledge, exam or test scores, chess patterns, learner's beliefs and degrees of correction, explanations of errors/misunderstandings, knowledge of prerequisite concepts, knowledge of sub-domains, knowledge to be validated, knowledge acquired, etc.

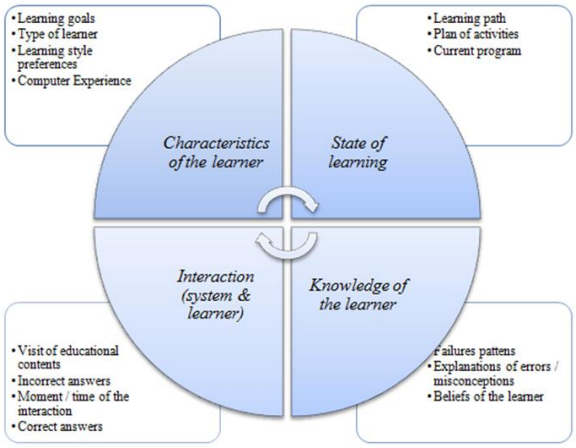

Figure 2. The composition of a Learner model in AHES

Figure 2 shows the proportion of the use of each category in AHES. It is impossible and not necessary to build a complete learner model with all the elements mentioned, because it requires too many resources. Most of the proposed learner models contain only a few parts of these four categories, especially the last two. Although researchers place less emphasis on learning status, it is useful for personalizing learning by considering the learner's learning path and progress.

3. Development of a learner model in Adaptive hypermedia educational systems

After presenting the functionalities of the learner model in different AHES. We will present in this section of the paper, the three phases of learner model's development in AHES. We will begin by explaining the process of learner model development and then we will present a comparative study concerning the three phases of the development process according to 10 AHES.

3.1. The process of developing a learner model in AHES

Despite these various attempts to model the learning that is characterized by a dynamic aspect, we always find it difficult to achieve this goal. The proposed approaches give us just a static view of the learner model, but in practice this model is in full development (the learner knowledge is evolving in the same module) to a dynamic view. In order to monitor the behavior of the learner in real time during training, we must adopt a model for dynamic management of the learning model.

All actions of the learner in a learning situation are not limited to valid or invalid actions (true and false), but these actions are characterized according to the learner learning path during his training. From this observation, we cannot represent the information from the system of each learner as a relative data. This demand putting our work in a probabilistic context due to the changes in the learner model during training. [19]

Figure 3 represents the stages of development of a model of the learner. In the data collection phase, they are three major steps: the collection of data about the user, the collection of data about the system and creating a learner profile based on this initial data collected.

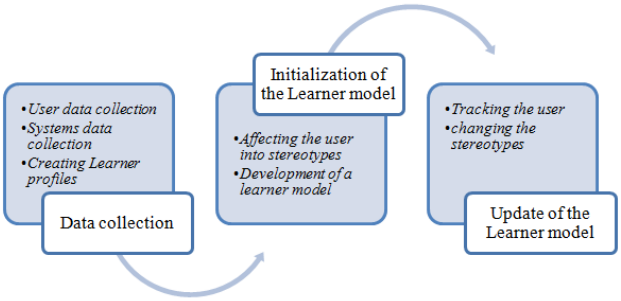

Figure 3. The process of developing a learner model in AHES

In the initialization stage of a learner model, the collected data undertakes a transformation process towards the model of the learner. This initialization process is realized through the implementation of several methods. The system affects the user to a specific stereotype according to the data collected. Then continue to collect data about the user all along his learning path using several methods like Bayesian networks or machine learning.

The information that is used to update the learner model can be retrieved, implicitly or explicitly from various sources of information. Among the sources of information, we find the information currently stored in the learner model. This information can be used as a source for which we derive new information or make changes to the alleged information. Furthermore, the information currently stored in the other system components may be useful.

3.2. The construction of a learner model in existing AHES

Table 2 represents a comparative between these different aspects of the construction of a learner model in AHES. We could notice that mainly all the AHES dispose of a system for data composition and representation.

Table 2. Comparative table between the different aspect of the constraction of a learner model in existing AHES

Construction of the learner model (data collection)	AHA	ADAPTWEB	AVANTI	ANATOMTUTOR	AHM	INSPIRE	HYPADAPTER	ELM-ART	HYNECOS	METADOC
Data Composition / structure	-	X	X	X	X	X	X	-	-	X
Data representation	X	X	X	X	X	X	-	-	X	X
Data collection general construction methods	X	-	X	-	X	X	-	X	-	X
Long-term / short-term model of data collection	-	-	-	-	X	-	X	-	-	-
Group / individual model of data collection	-	-	-	X	-	-	-	X	X	-
Empirical studies	-	X	-	-	-	-	-	-	X	-

The main difference between this AHES is the methods used to collect data; we could notice that the old AHES based its data collection in general construction methods, and the specific AHES used more individual methods to extract precise data about the user.

The construction of an MA concerns the determination of the composition and structure of a learner model. For example, what categories of information should be included in the learner model? What concrete elements are needed? And what are the links of these elements between them? We must also consider how to effectively represent this structure and these elements. Some Hypermedia concretely presents the use of certain formalisms of representation. The process or method of construction indicates how to organize and acquire this information and knowledge. For example, how to extract knowledge from empirical studies.

3.3. The inisialisation of a learner model in existing AHES

The initialization of a learner model is a fairly important step in the development process. Researchers have exploited four ways to initialize a learner model: through questionnaires or pre-tests, by stereotypes, by the previous cases and by the default values. Among them, stereotypes are most often used. Stereotypes represent the knowledge and characteristics of typical user classes. So each student is assigned to one of the predefined classes (i.e.: stereotypes). The major task of initialization is to select the appropriate stereotype for a learner. The questionnaires are practical and relatively easy to implement. Therefore, they are used in several systems.

Table 3 represents a comparative between these different aspects of the initialization of a learner model in AHES.

Table 3. Comparative table between the different aspect of the initialization of a learner model in existing AHES

The initialization of the learner model	AHA	ADAPTWEB	AVANTI	ANATOMTUTOR	AHM	INSPIRE	HYPADAPTER	ELM-ART	HYNECOS	METADOC
Pre-tests / questionnaires	-	X	X	-	-	-	-	X	-	-
Previous cases	X	-	-	-	-	-	X	-	-	-
Stereotypes	-	-	X	X	-	X	-	-	X	X
By default	-	-	-	-	-	-	-	-	-	X
Machine learning	-	X	-	-	X	X	-	X	-	-

Sometimes, to know the initial level of knowledge of the learner, the learner is asked to do a simple test before starting his apprenticeship. The result of the test could be used to initialize some learner model values, or to show the progress of learning.

Using previous cases to initialize the model is an interesting method. Previous experiences (models) of individual students or groups are used as stereotypes for future learners. Default values are used frequently in traditional systems. The initial values are assigned and then adjusted as appropriate in the treatment process.

3.4. The update and management of a learner model in existing AHES

The methods and steps of a learner model management are related to the appropriate times to update the data or knowledge stored in the models. The learner model maintenance mechanism is specific to everyone because it has a close relationship with many aspects of the model, such as its structure, mode of representation, use, and so on.

Table 4 represents a comparative between these different aspects of the update and management of a learner model in AHES.

Some parameters in the category of personal data are used to identify the learner, for example the name, the user name or login name, the email, etc. Some personal data (eg age, experiences, gender, training, etc.) and some characteristics of the learner (learning purpose, type / style of learning, computer experiences, level concentration, preferences, etc.) are used to initialize the model, especially to select the appropriate stereotype for the learner. A stereotype represents the common characteristics of the learning style. Learning paths or activity plans could also be exploited to preserve the present or past states of the learner The statistical parameters concerning the interaction between the learner and the system (the frequency of a specific error, the units visited more frequently, etc.) are the results of the calculation or reasoning based on certain visible parameters on the actions of the learner. the learner. They could also change some characteristics of the learner, including the level of concentration. Interaction parameters and characteristics are used to evaluate the learner's knowledge. Conversely, the level of knowledge assessed could also influence / modify certain characteristics of the learner.

5. The modeling approaches used for learner modelling in existing AHES

A learner model is a combination of all relevant data on the learner in relation to a learning environment. There are common types of information among learners' models such as object domain information, goals, motivation, training and experience, cognitive skills, preferences and demographic training data.

To develop and manage the learner model, several methods/techniques have been used. Table 5 represents a comparative between these different modeling techniques and models used in modelling the learner in AHES.

6. Discussion

Learner models can be used in very different ways, depending on the actions and characteristics of the learner in the system. Since there are different types of adaptive e-Learning systems, the applied learner models are different.

In many systems, the learner model may not be explicitly described as a simple functional module. It can be spread over several elements of the system. Thus, it is clearly visible what is connected to the model of the learner. Therefore, a learner model may not be available as an additional component but properties, which are related to a user model and are assigned to the long-term model user.

We could say, based on this study, that the learner model is an essential element in adaptive e-Learning systems. The adaptation of an e-Learning system primarily involves the selection and presentation of each successive teaching activity based on the full scope of the learner's knowledge of the subject taught and other relevant characteristics of the subject. As a result, the learner model is used to change the interaction between the system and the student to meet the individual needs of the students.

A learner model must be built, initialized and updated. Initializing a learner model is an important topic, where an appropriate way to gather the requested information has to be found. In particular, the effort for the user during initialization should be considered as this process affects the accuracy and usability of the learner model and the entire system. To keep the information stored on the learner updated, the modification of learner information must be included in the learner template. After the information within a learner's model is changed, the new information must be delivered. Delivery affects systems that use the learner model and should keep information consistent across all places where it is used.

7. Conclusion

An adaptive system needs information about the target to which it adapts. Since this target is most often adaptive to the learner of the adaptive system, a learner model is required. By using a learner model, an adaptive system can use this learner model in three different types of system actions. The system can interpret the actions of the learner differently regarding the features stored in the learner's model. For example, users with dyslexia may have a particular problem with a few words. The system recognizes these typos and automatically corrects the entry. In the other direction, the actions of the machine or the output of the system can be adapted to meet the needs of the user, and finally, internal actions can be influenced by the information stored in the user's model.

Table 4. Comparative table between the different aspect of the update and use of a learner model in existing AHES

The update and management of the learner model	AHA	ADAPTWEB	AVANTI	ANATOMTUTOR	AHM	INSPIRE	HYPADAPTER	ELM-ART	HYNECOS	METADOC
Learner identification	X	X	X	-	X	X	X	X	X	-
Initialization of the model	X	X	-	X	-	-	X	-	-	X
Retention of learning states	X	X	-	-	X	-	X	-	X	-
Update of the model	-	-	-	-	X	-	X	-	-	-
Inference of other parameters	-	-	X	-	-	-	-	X	-	-
knowledge modeling	-	-	-	X	-	-	X	-	-	-

Table 5. Comparative table between the different methodes/approches used in learner modelling in existing AHES

Learner model modeling techniques/ methods	AHA	ADAPTWEB	AVANTI	ANATOMTUTOR	AHM	INSPIRE	HYPADAPTER	ELM-ART	HYNECOS	METADOC
Stereotypes	-	-	X	X	-	X	-	-	X	X
Overlay Model	X	-	X	-	X	-	X	X	-	-
Perturbation model	-	-	-	-	X	-	-	-	-	-
Differential model	X	-	-	-	-	-	-	-	-	-
Machine Learning	-	X	-	-	-	X	-	X	-	-
Bayesian Networks	-	-	-	-	X	-	X	X	-	-

The information stored in a learner model varies between different models and depends on the adaptive e-learning system surrounded or often used. To provide as much interoperability for a learner modeling system to be used by multiple systems, it is necessary to agree on the information contained in a learner model. These agreements are represented by standards. There are several standards in the field of user modeling that we will describe in the next chapter.

As a conclusion, it is safe to say that the learner model plays an important role in most hypermedia system and adaptive educational hypermedia systems in particular. We have presented in previous work, a probabilistic approach to manage dynamically the learner model in AHES [20] [21] with an approach that can manage two types of independent and specific information of the domain of the learner, and that can be relevant to the three stages of the construction of the learner model. And we have also presented a process to combine the stereotypes method and Bayesian networks to initialize the learner model in AHES [22] in a probabilistic work frame to respond to the problematic of uncertainty in the learner model.

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