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Design and development of a computer system adaptative for the management of the learner profile

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Abstract

In the educational context, an adaptive hypermedia will make it possible to better guide the learner in his learning, to offer him courses and educational content that are adapted and personalized, and to take into account his learning profile.

The idea developed in this article lies in the design and management of a valid learner model for all adaptive hypermedia systems (adaptive, macro-adaptive e-learning, ITS, AHES).

Through this work, we first offer an overview of the learner profile by citing the difference between the model and the profile of a learner. Next, we deal with the learner model in adaptive systems by identifying the different systems. Then, we process learner modeling based on learner model content, specific information domain, and independent information domain and learner model components. Finally, we propose the process of developing a learner model: Steps and techniques especially data collection, learner model initialization and learner model update.

Keywords: Model and learner profile; Adaptive systems; Learner Modelling; E-learning; Artificial intelligence.

1. Introduction

Learner profile and learner modeling are used as one term to distinguish between a learner profile and a learner model; we will start by describing the difference between the two terms before getting into the reasons. Construction, use and applications of the learner profile or model.

2. The difference between the model and the learner profile

Koch describes the user profile as a simple model of the learner [1].

The learner profile represents cognitive abilities, intellectual abilities, and intentions, learning styles, preferences and interactions with the system. These properties are returned after assigning values to them, which may be fixed or change over time depending on the content and amount of learner information that is stored in the learner profile, a the learner can be modelled. Thus, the learner profile is used to retrieve the information needed to build a learner model. Koch describes a learner model as a representation of the system's beliefs about the learner (called user by Koch and Kay) [1].

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In Figure 1, the "real world" learner is perceived by the system via the human-machine interface. The learner model is based on this information and therefore only represents a small part of the actual learner. Nevertheless, the learner model must represent the necessary characteristics of the learner with respect to the context of the application.

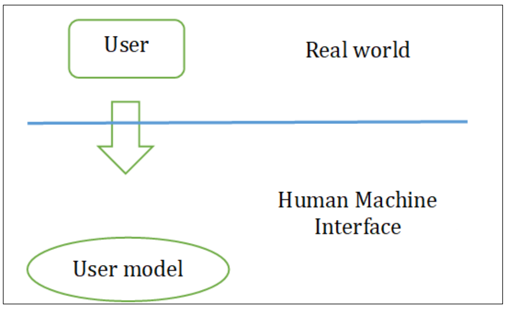

Figure 1 The learner and the learner model according to Kay [2]

2.1. The need for the learner model

Koch describes the application of the learner model as follows [1]:

“Users are different; they have different backgrounds, different knowledge on a subject, different preferences, different goals and interests. To individualize, personalize or customize actions, a user model is needed to allow the selection of individualized responses to the user.

Therefore, the behavior of an adaptive system varies depending on the data coming from the model/learner profile. Without knowing anything about the learner using the system, which would behave the same for all learners.

2.2. Applications of the learner model

Learner modeling applications are diverse (user models): search engines, recommender systems, or help systems. Furthermore, not only attributes of a learner (egg: domain knowledge, preferences, goals, etc.), but also limitations (egg, disabilities like color blindness, etc.) to perception of the learner must be returned in a model of the learner. If these limits are to be violated, it is important to know the least worrisome options.

2.3. Two -The learner model in adaptive systems

The purpose of user modeling is to be able to customize system responses. User modeling is the way to represent a user and their behaviors. It also concerns how to exploit the knowledge available about it.

The role of a learner model within an adaptive system. According to Kay, a learner model can help with adaptation three main ways. These are shown in Figure 2. [2].

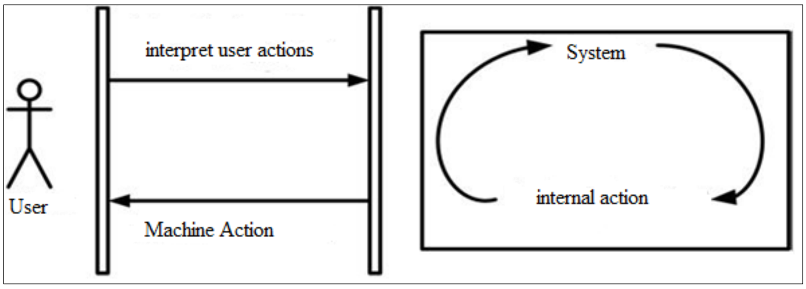

Figure 2 The role of the user model in adaptation [2]

The arrows represent possible user actions to the interface that are available through the user interface, such as mouse actions, keyboard typing, and audio/video input.

A user model can support the system in interpreting this information.

In addition, the learner model can help the system interpret incorrect actions of learners. Kay lists the applications of the model in different fields such as natural language understanding, command line interpreters, spelling mistakes by dyslexic users or typing problems by users with motor difficulties [2].

The arrows interpreting the actions of the machine represent the actions initiated by the system.

A learner model can be used to control and modify these actions to the learner's preferences. This process consists of adapting the behavior of the system and turns to the learner or the adaptation of the content as well as the presentation of the content.

Therefore, adaptive hypermedia systems focus on adapting navigation and content by emphasizing preferences and domain knowledge enabled in the user model.

The use of a learner model for adaptation within the system. The learner model supports the system during internal actions. Often his actions are filtering processes where the information received is filtered.

After this internal process, the system generated an action at the interface. The model of the learner [2] also affects the form of the presentation of this action.

A combination of these measures is often used by adaptive systems. Koch lists seven purposes of a user model:

- Assist a user when learning a given subject;
- Provide adjusted information to the user;
- Adapt the interface to the usé;
- Help a user find information;
- Give the referral of users about its knowledge;
- Support collaborative work;
- Provide assistance in using the system [1].

These objectives are very learner-centered and do not explain where the learner model influences the system.

2.4. The learner model in adaptive e-learning systems

Learner models can be used in very different ways, depending on the actions and characteristics of the learner in the system. As there are different types of adaptive e-learning systems, the learner models applied are different. We will describe in this part the learner models and their use within the system by examining adaptive macro systems, intelligent tutorial systems and educational adaptive hypermedia systems.

In many systems, the learner model may not be 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 learner's model. Therefore, a learner model may not be available as an additional component but properties, which are related to a learner model and are assigned to the long-term model learner.

2.5. The learner model in macro-adaptive systems

In macro-adaptive systems, the adaptation of instructions is handled on a macro level of personalization. Instructional decisions are based on learner traits gathered from self-reports, questionnaires and pre-tests. For macro-adaptive systems, it is not necessary to know domain knowledge during instruction. The pedagogical objectives are determined for each learner according to his profile, prior knowledge, and other aptitude and motivation data. The acquired knowledge is generated by comparing the results of the pre-test and the test after the course [3].

2.6. The learner model in ITS

Intelligent Tutoring Systems (ITS) basically consist of, as we have described, four components as shown in Figure 2. Three of these four components contain a specific user model, namely the expertise module, the of the student and the tutoring module.

The expertise module contains an expert model, the student module contains a learner model and the tutoring module contains a tutor model or a pedagogical model.

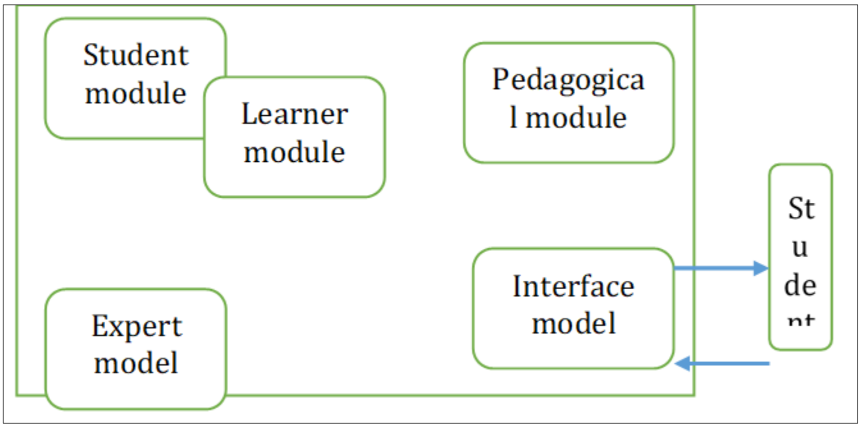

Figure 3 The components of an ITS [4]

The expert model incorporates the necessary domain knowledge to provide adaptive feedback, question answers, and problem-solving support. The model of the learner represents the belief of the system on the knowledge of the learner. In addition, the learner model can include learner characteristics and preferences.

The pedagogical model contains rules that allow the system to teach like a tutor. These rules take into consideration the learner properties stored in the learner model and use the expert model to compute the appropriate instruction for the current learner. With this pedagogical model, the tutoring module is able to achieve:

- Knowledge diagnosis;
- Strategic functions;
- Prediction functions;
- Evaluation functions;
- The development of knowledge;
- Error remediation;
- Representation of domain content;
- Control of the exploration space.

The student model is used to adapt these functions to the needs of each student, According to [4] [5]. To help a student during the development of knowledge, and ITS foresees four stages. These stages are what to teach, when to teach, how to teach and finally the implementation of teaching actions [6].

2.6.1. Knowledge development

What to Teach: In this step, the learner model provides information about the learner's current state of knowledge. With this information, the tutoring module is able to choose the curriculum sequence, provide active help and feedback during the problem-solving process, or to provide assistance upon request.

The sequential curriculum is used to provide the learner with the most appropriate sequence of learning.

The learning sequence consists of series of knowledge units to be learned and tasks like examples, questions and problems to be solved. There are two subtypes of curriculum sequence:

- High-level sequencing (knowledge sequencing): it uses the learner's model and domain knowledge to select the teaching concept.
- Low-level sequencing: it only uses the learner's model to determine the next learning task (an example, a test or questions) [7].

Using recorded learner behaviors, the system is able to provide active help and feedback. Intelligent feedback to the student's solutions, such as error feedback or comparing the student's solution to an example solution, can help improve the learner's understanding of this topic. Also, additional tips or reminders help learners during the solution process.

When to Teach: The appropriate time for knowledge development is calculated using the learner model. This is important when active help is needed during the problem solving process.

How to Teach: Appropriate instructional actions such as explanations, trials, examples, or problems are chosen using the learner model. These training actions are influenced by the learning style or preferences stored in the learner model.

2.6.2. Implementation of training actions

At this stage, some teaching actions can be modified according to the learner's model. For example, if a learner has advanced knowledge in a subject, only a small explanation is given to solve a problem.

2.6.3. Remediation error

According to Self, eight methods of remediation can be identified; error definition, explicit remediation, implicit remediation, counter-examples, demonstration of a method of solution, access to previous experiences, attempt at repetition and tactical retreat [8].

The error definition provides a textual description of the error and a recommendation for correction. Explicit presentation of correct knowledge is given by explicit remediation while implicit remediation prompts correct knowledge or actions and shows notes to the learner. Counterexamples are situations or problems generated by the system. The user model gives access to previous experiences where those experiences are stored.

2.6.4. Exploration space control

The STI automatically controls the exploration space, while the learner navigates through the domain space. This control takes place in the form of limiting information resources, the number of search paths and tools, and then the amount of information presented. This concept of control is used to reduce the learner's cognitive load since too much information or opportunity reduces the learner's attention and leads to distraction. The control of the exploration space is based on the learner's skill level, experience, etc... [9].

2.7. The learner model in AHES

To describe learner models in educational adaptive hypermedia systems, possible adaptations must first be introduced. According to Brusilovsky, mainly the presentation of hypermedia and navigation through hyperspace can be adapted as illustrated in Figure 3. These two ways are subdivided into several adaptive hypermedia technologies [10].

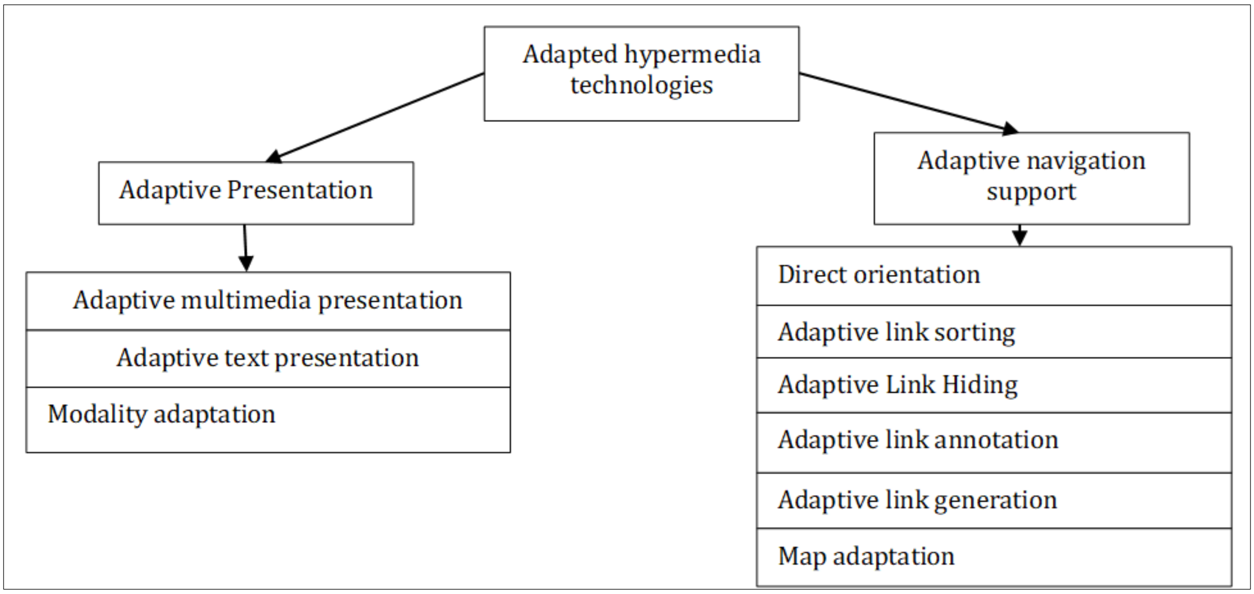

Figure 4 Adaptive hypermedia technologies [10]

To be able to adapt the presentation of learning content and navigation to the needs of the learner, a model of the learner is needed, including objectives or tasks, knowledge, prerequisites and learner preferences. These properties of a learner are used to make adaptive decisions by adaptive hypermedia systems. In addition, the learner's recent templates also store individual interests and traits.

Individual traits include personality, cognitive factors, and learning styles, but are not easy to extract. They represent stable characteristics of a learner, while interests change over time [3].

Brusilovsky describes a new type of adaptation for web-based systems. The nature of web-based systems allows the user to change their learning environment. Thus, several, different hardware, software and platforms can be used by the same user. This requires adaptation to the user's environment and has become an important problem [10].

According to De Bra, an adaptive hypermedia system should consist of:

- A domain model: It describes how information is structured and linked together.
- A learner model: It represents a set of learner characteristics and preferences for navigating the hypermedia space
- An adaptation model or pedagogical model: consists of pedagogical rules, which define how the domain model relates to the learner model in order to provide the adaptation.
- An adaptation engine: is responsible for processing the adaptation by manipulating the navigation fragments or the content of the page before the adapted page is sent to the user interface [11].

The models proposed in the work of De Bra et al. and the learner model in ITS are identical. The domain model serves the same purpose as the expert model in ITS.

Both models represent domain knowledge. The tutor or pedagogical model in an ITS describes the pedagogical rules for instruction, which is comparable to the adaptation model in an AEHS. Finally, the learner model of the AHAM reference model also has the same purpose as the learner model in an ITS. To conclude, there are essentially the same learner models with the same usage in both types of systems. The reason for this is historical development, since the development of AEHS is based on ITS, which were invented before AEHS.

Translated with www.DeepL.com/Translator (free version)The learner models described in this part give an overview of the models applied in different types of systems. Preferences and characteristics are modeled in a student or learner model by all systems. The user model environment, the roles they have, and what types of user models are used in different types of systems.

3. Learner modeling

A learner model represents the system's beliefs about its primary target user, the learner, and provides the information needed to tailor instruction to the learner's needs. This necessary information is represented by the content of a learner model. All of the content can be grouped about different properties of a learner. These groups are arranged in the components of a learner model.

3.1. The content of the learner model

The learner model should contain information about the learner's domain knowledge, progress, preferences, goals, learner interests, and other learner information that is important to learners. Systems used [12]. Brusilovsky indicates that learning models can be classified according to the nature and form of the information contained in the models. Considering the subject domain, the information stored in a learner model can be divided into two large groups: the domain of specific information and the domain of independent information. Figure 4 represents the components of each information domain; the combination of these two information domains gives a complete view of the learner for adaptive systems [4].

3.1.1. The field of specific information

The specific information domain represents the learner's state and level of knowledge and skills in a particular domain. This is the knowledge model can be based on different types of models or a combination of these types. [4]:

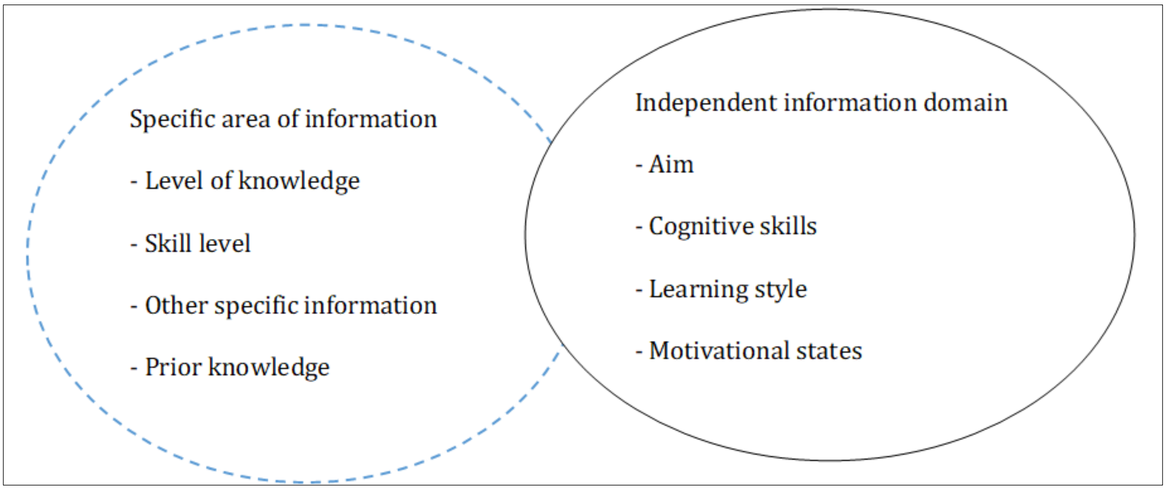

Figure 5 The content of a learner's model [13]

Scalar model

An identifier as a number in the range of 1 to 5 describes the learner's level of knowledge across the whole domain. The scalar model is the simplest form of a knowledge model and does not provides no information about knowledge in a subdomain [6].

Overlay model

A complete information domain consists of a set of knowledge elements and represents the knowledge of the expert in that domain. It describes the learner's knowledge as a subset of the full domain model; some measure is assigned representing the learner's estimated knowledge about that item. The measure can be a scalar (for example an integer, a probability measure or an indicator) or a vector estimate [14].

Error Model

A disadvantage of overlay models is the inability to store errors made by the learner. For this reason, bug model or error model has been developed. With an error model, it is possible to define and reflect the erroneous behaviors of learners and the reasons for these errors. It is assumed that one or more perturbations exist for each element of the knowledge of the domain model. Thus, the learner's disturbance model represents a subset of all possible disturbances, which are the cause of incorrect learner behavior concerning particular knowledge items [4].

Genetic model

Are used to describe the development of learner knowledge. This process can evolve from simple to complex or from specific to general. It is possible to describe a genetic model by a genetic graph, where the nodes and the relations between the nodes represent elements of knowledge and their interactions [6].

Other areas of specific information According to Han, can be added [6]:

- Prior knowledge of the learner's field;
- Records or learning activities (lectures taken, number of requests for help, time to solve problems);
- Records of tests and evaluations.

Finally, the additional domain specific information may contain information needed for specific purposes of the learner model related to the subject domains.

3.1.2. The field of independent information

The domain of learner-independent information can include learning goals, cognitive abilities, motivational state, background and experiences, preferences, as well as factual and historical data [6]. Necessary to allow adaptability

Objectives

To establish the correct teaching strategy, it is important to know the learner's objectives. These objectives answer the questions: why the learner uses the e-Learning system and what does the learner want to achieve. Objectives can the learning objective, which is relatively stable for a course unit. Problem-solving goals, which may change from problem to problem.

Cognitive skills

Are the intellectual abilities for all kinds of different cognitive performance? For example, musical, mathematical and reading aptitude…

Factual and historical data: demographic data such as name, age, parents, etc. the ID is often stored in learner models. This information, combined with other factual data such as interests, is necessary to initialize a model of each learner [6].

Motivational states

To measure learning interest in teaching, learner motivational state is measured using a number of long-term and short-term parameters. These parameters are, for example, effort, attention, interest, distraction, persistence, etc. These parameters are related to other factors such as level of knowledge, preparation, subject complexity and learning outcomes.

In this model of the learner, a Bayesian network represents the state of motivation, where the graph encodes the dependencies between the facets of motivation and learning activities. For example, a path from the distraction property to attention indicates that the distraction is to influence the learner's attention [15].

Contexts and experiences

To derive the parameters of the learner model, information about prerequisites and experiences are used. Background information includes skills that can influence the achievement of learning. This information is for example, the profession, work experience or prospects [4].

Experience represents knowledge about the learning environment. The learner, who is new to a particular learning environment or even new to e learning, needs support from different systems, no matter whether they are novices or experts in the subject area. This information could be used to select the appropriate adaptive navigation method.

Preferences

Learners have different preferences related to certain aspects of the learning environment; the learner must inform the system directly or indirectly about his preferences. It is important for an adaptive learning system to present and organize learning material based on learner preferences. Learner preferences can be used to form learner groups. This technique is called group modeling, where learners with the same preferences form a group. Two parts of preferences are learning style and multiple intelligence, they are mutually related to each other.

Howard Gardner first described multiple intelligence theory in 1983. His latest research indicates that there are eight distinct forms of intelligence: [16].

- Linguistic intelligence is the ability to use words and language is hearing ability
- Intelligence/mathematical logic is the ability to use reason, logic and numbers. These learners think conceptually in logical and numerical patterns to make connections.
- Spatial intelligence is the ability to perceive the visual. These learners tend to think in pictures and need to create vivid mental images to retain information;
- Kinesthetic intelligence is the ability to control body movements and manipulate them
- Musical intelligence is the ability to produce and appreciate music;
- Interpersonal intelligence is the ability to relate to and understand others. These learners try to see things from other people's point of view in order to understand how they think and feel.
- Intrapersonal intelligence is the capacity for self-reflection and being aware of one's inner state.
- The naturalist describes the ability to recognize and classify many species of the environment

Gardner said that everyone has all of these eight intelligences, but to varying degrees. Considering multiple intelligence during the adaptation process, the learning environment is able to adapt the learning material, according to the learners' strengths, which makes it possible to hold the learning progress on a maximum [16].

3.2. The components of the learner model

Before dividing a learner model into components, the information stored about the learner must be analyzed and grouped regarding the different types and levels of information.

The components are strongly related to the application of the learner model, but it is common to build a performance and a model of the teaching story.

- The performance model stores data related to the assessment of the learner's global skills, as well as data related to the learner's prior knowledge.
- The teaching history model keeps track of the material presented to the learner during instruction and the learner's mastery of the units of instruction [17] [18].

Additional components are needed to provide complete learner information. Zhou and Evens list two additional components, the response history and the solution file. A learner response history is attached to each unit of instruction and stores information about the learning material and learner responses during that unit. The amount of errors and the description of these errors, which when done during the problem solving process are stored in the solution folders [17].

Another approach is to divide the learner model into several components where the learner model is divided into three components: a profile, a cognitive overlay model and a safe overlay model [19].

The learner profile stores information such as name, age, learning style, etc. The system's beliefs about the learner's knowledge are recorded in the cognitive overlay component while the course overlay component offers information about the learner's interactions with the system.

To describe the technical details on a learner model, additional technical components are used. The technical components are for example a data reader, a data author and a session manager. The data reader and data author components are responsible for providing access to a data store.

A session manager controls and coordinates all other components and is considered as the control unit of a learner model [18].

A learner model is a combination of all relevant learner data in relation to a learning environment. The content of a learner model is arranged into several components according to the type of information in order to collect the necessary information, different techniques are used.

4. The Process of Developing a Learner Model: Steps and Techniques

There are several methods for constructing a learner model. The construction of a learner model is followed by the initialization of this model, which must be filled with initial data. To keep the information stored in the learner model up-to-date, changed learner characteristics must be determined to meet the requirement of representing the current aspects of the learner. In addition to updating the information stored in the user model.

4.1. Data collection

Before a model must be used, it must be constructed. There are many methods, which can be applied during construction.

4.1.1. Automatic learning methods

They are applicable for the modeling of the cognitive processes, which underlie the actions of the learner; they include learning rules, probabilistic methods and methods of learning from instance cases. The model learner to benefit from the use of machine learning methods through their increasing accuracy, increasing efficiency and even scalability to where it has not been possible to build a model of the learner before [20].

According to Webb, the purposes for which machine learning methods can be used are modeling the differences between learner skills and expert skills, modeling learner motives or behavioral preferences, and even modeling learner characteristics. However, although the first two goals are addressed very often, the modeling of learner behavior or characteristics is still very rare [21].

4.1.2. Bayes/Bayesian methods

Bayesian methods and their applications, such as Bayesian networks, are very powerful, they are related to machine learning methods and used in user models and are therefore described separately.

Bayesian methods support the use of probabilistic inference to update and improve belief values.

According to Li and Ji, Bayesian networks are used for plane recognition; the inference of user needs and the state of affective evaluations. To infer the state and needs of the current learner, pauses and errors are considered. Furthermore, goals and needs are inferred using the learner's context, actions and requests [22].

The current emotional and mental aspects of the learner are an important indication of the state, intention and needs of the learner. Therefore, the affective state is a point of interest and can be generated using Bayesian networks. For example, emotional states are modeled as consequences of how well the current action matches the learner's goals and preferences.

4.1.3. The superposition model

The superposition model, which was introduced by Carr and Goldstein in 1977, is based on the aspect, that the learner model is a subset of the expert model. The expert model is subdivided into several smaller parts and categorized into specific topics or concepts. Each of these small elements can be connected to a particular model of the learner [20].

Overlay models are widely used in learner modeling systems, where they are applied to model the field of education. Learner knowledge is built on a concept-by-concept basis and updated as the learner progresses through the course. Brusilovsky indicates that a superposition model allows a flexible model of the learner's knowledge for each subject [23].

The complexity of a recovery model depends on the structure of domain knowledge, where granularity is important. Also, the estimate of learner knowledge is important and is measured by looking at the sections the learner has read and the tests the learner has taken [24].

4.1.4. Stereotype methods

The creation of stereotypes is a very common way of modeling the learner. New learners are classified and assigned to a stereotype according to their initial characteristics of the learner model. There are two types of stereotypes: fixed and default. In fixed stereotypes, learners are cast according to their performance in a predefined stereotype that is determined by academic level. Default stereotypes is a much more flexible approach. At the start of a session, learners are stereotyped at default values, but as the learning process produced and learner performance data are obtained, the settings of the initial stereotype are gradually replaced by more individualized settings. [25]

The problem with using stereotypes is the work of constructing and fulfilling the appropriate stereotypes. According to Kobsa, the developer of a learner modeling system should think about tasks such as identifying learner subgroups, identifying key characteristics, and representation in hierarchical stereotypes. Subgroups subdivide the community of potential system learners. After identifying subgroups and their main characteristics, a stereotype is assigned to each subgroup [26].

Additionally, key characteristics or triggers need to be identified in order to be able to determine a learner's suitability to a specific subgroup. The amount of these features should be kept very small to provide quick and easy assignment to a subgroup.

After all the subgroups are identified and the associated characteristics are assigned, a representation of this structure is constructed. The collection of all the represented features of a subgroup is called a stereotype for that subgroup. If part of the content of a stereotype is the content of another stereotype, it is possible to construct a hierarchical structure of all the stereotypes [26].

It is also possible to form stereotypes based on the background knowledge of the learner. Mostly a linear hierarchy of stereotypes like beginners, intermediates and experts is used.

Another modeling technique, which is similar to stereotype modeling is group or community modeling. The community approach was implemented in Doppelgänger [27], where communities represent a group of learners. The difference to stereotype modeling is that the learner is categorized by membership in multiple communities. If a user's model does not have any explicit information, a particular characteristic of the value is retrieved from the communities owned by the user.

4.1.5. Recognition of the plan

Plans are used to describe learner's intentions and desires, where a plan is a sequence of learning actions that achieve a certain goal. Regime recognition is based on observation of learner input actions. These systems try to determine all possible learning plans, which are valid on the observed actions. This calculated set of plans can be reduced by taking into account new learners' actions [22].

According to Kobsa, there are basically two types of techniques used to recognize the learner's plan. In the first approach plan, libraries are built. A plan library contains all possible plans and the selection of the current plan is based on the actions observed by matching these actions to the set of plans. The problem with this technique is that all allowed sequences of learner actions must be stored in a plan. This requires a lot of up-front computational work and huge storage for the plan library [26].

The second approach is called plan building, where the system controls a library of all possible learner actions combined with the effects and conditions of those actions. The sequence of actions of the learner is enriched by all the successive actions of the learner. Possible next user actions are calculated by comparing the effects of actions with preconditions of actions stored in the library of previous actions [26].

In general, the in-plane recognition method is limited by the requirement that all possible learning planes must be specified beforehand.

The process of building a model is in most cases method-based. Rather a combination of several methods is applied. Mainly the methods of stereotypes and recovery are used.

4.2. Learner model initialization

Initializing a learner model is the process of collecting information about the learner and transferring that information into the model. The initialization process is also a problem in the field of recommender systems.

This section describes the methods, how learner information is retrieved. According to self, a learner model can be initialized in three ways: [12].

4.2.1. Explicit questions

Initial learning models are often built by directly asking the learner. This method is a very effective way to obtain general information about the learner. The problem is to find the appropriate amount of questions and to get the optimal amount of information on those questions on the other side; too many initial questions could irritate the learner and increase the declination to the system. The worst-case scenario would be if the learner leaves the system and never returns

On the other hand, too few or badly chosen questions do not allow the system to extract enough information to initialize the learner's model [28].

An alternative that would reduce the number of questions is to use adaptive questionnaires [29]. They apply adaptive methods to optimize the length of the questionnaire by picking up informative questions using Bayesian methods.

4.2.2. Initial tests

By asking the learner to take a test, the initial parameters of the learner model can be obtained by analyzing the test results. In order to control the length of the trial, the concept of neighborhood of knowledge can be applied. The first tests are often used to obtain information about the domain knowledge of the learner [12].

The learner modeling system can use stereotyping methods to group similar learners into categories. Although stereotyping is very powerful in providing considerable information based on just a few observations, they do not provide the learner with an accurate model. The information needed to be able to apply stereotypes can be retrieved using explicit questionnaires. Another method is to assign a new and unfamiliar learner to a default stereotype and refine the applied stereotype by observing the learner. It can also help reduce initial questions [6].

After filling the learner model with information, keeping this information current becomes important.

4.3. Learner model update

Updating a learner model means updating the data and information contained about a learner. Since the dynamic and short-term characteristics of learners are not constant properties, change over time must be considered by the learner model. For updating a learner model, information sources and updating methods are needed.

4.3.1. Information used for updating a learner model

The information used to update a learner model can be retrieved from different sources of information. As a first step, the information currently stored in the learner model must be considered. This information can be used as a basis for inferring new information or making changes to inferred information. Additionally, information currently stored in other system components may be useful.

According to Kinshuk, there are several ways to get information from the mentioned sources of information [30]:

Implicit; Explicit; Structural and Historical Acquisition.

The implicit acquisition of information is based on the observation of the learner's actions during the learning process. Considering the direct dialogues between the system and the learner, they lead to the explicit acquisition (for example of an explicit questionnaire). Structural acquisition is achieved by analyzing the interrelationships between the elements of the study program.

Assumptions based on the learner's experience are made during historical acquisition of information. Considering the information available to update a learner model, there are different methods that allow how this information is used to update the learner model.

4.3.2. Methods used to update a learner model

Information to update the learner model must be derived by analyzing learner responses, problem-solving processes and learner actions. These three methods are analytical processes; they are called cognitive diagnosis defined as the process of inferring a person's cognitive state based on that person's performance. Another method to update a learner's model is to determine the old data and not by using this old data another time [31].

Analysis of learner responses

Also called performance measurement [4]. Questions for an exam during instruction can be divided into simple questions and complex questions. Simple questions are only tied to a specific program element while complex questions require knowledge of more than a single program element. Therefore, learners' responses to these two types of questions should be treated differently. For example, a correct answer to a simple question increases the relevance of the related program element, while an incorrect answer decreases the relevance of the underlying program element. Analyzing the answer to a complex question needs more effort. These changes should be considered and an update of the affected properties of the learner model should be made.

Analysis of the problem solving process

The analysis of the problem solving process requires a technology, where all possible correct rules, which can be used by the learner during the solution process, are available. By combining these rules with a collection of misconceptions responsible for errors that may occur, the system is able to calculate and detect all measurements and correct solution misconceptions made by the learner at each step of the solving process. Problem [4].

Analysis of learner actio*ns*

Learner actions can be analyzed by considering them as results of the acquisition of a set of curriculum elements or misconceptions. This is possible if the domain name of the subject is known. For this, a simple tracing of the actions of the learner is necessary. This method is called problem tracing [4].

Updating old data

Considering that, up-to-date data reduces the value of old data in the learner's model. This gives significance to the data, which is derived from recent measurements. The process of refreshing old data is based on the assumption that the time elapsed since this old data was stored, diminishes the importance and influence of old data to the learner's current state [21].

4.3.3. Techniques used to update a learner model

Modeling techniques are important when building a model of the learner. It is common for a learner model to use a combination of several modeling techniques, in particular a combination of stereotyping and covering methods is applied. The modeling technique used also defines the scope and accuracy of the learner's model. In general, the motivation is to build a broad learner model with as much precision as possible.

After construction, the model must be initialized. This step requires information, which fills the learner model but saves learner effort. Therefore, the information collected should be used in the best possible way to infer much of the information. Deducing data requires the use of smart methods like Bayesian methods or machine learning methods, which lead again in many efforts for initialization. Keeping the learner model updated requires learner observation during instruction. The only source to maintain currency of information is to consider the interactions between the learner and the system during instruction.

5. Conclusion

An adaptive system needs user information, a user model is needed.

By using a user model, the adaptive system can use this model in three different types of system actions. The system may interpret the user's actions differently regarding the characteristics stored in the user's model. In other sense, machine or system output actions can be tailored to meet the user's needs, and finally, internal actions can be influenced by the information stored in the user's model.

In the context of adaptive e-Learning systems, a user model stores information needed to adapt instruction. Adaptive macro systems employ a simple user model. The instruction is adapted for the advance mode and no adaptation is processed during the instruction. The user models used in ITS and AEHS are more sophisticated and store more information about the user. Emphasis is placed on the interactions between users and the system during instruction and on knowledge of the domain. This makes it possible to adapt the system to the preferences and the current state of knowledge of the user.

Considering the application of a user model in an adaptive e-Learning system, a learner model represents the user model. Therefore, the difference between a user and a learner model is the specific use of the learner model. A learner model is mainly used in e-Learning systems, while a user model is more general and does not focus on a specific application area.

A learner model must be built, initialized and updated. The initialization of a learner model is an important topic, where an appropriate way to gather the requested information must be found. In particular, the effort for the user during initialization must be considered because this process affects the accuracy and usability of the learner's model and the whole system. To keep the stored learner information up-to-date, changing learner information must be included in the learner model. After the information within a learner model is changed, the new information must be delivered. Delivery affects systems that use the learner model and should keep information consistent across all locations where it is used.

The information stored in a learner model varies between different models and depends on the adaptive e-Learning system surrounding it. 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.

Compliance with ethical standards

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