Learner Model in Adaptive Learning

Loc Nguyen, Phung Do

***Abstract*—**Formerly, Learning Management Systems (LMS) support well for interaction between learner and lesson, learner and teacher. However, every student has individual features such as: knowledge, goal, experience, interest, background… So, there is emergent demand for tailoring learning material (lesson, exercise, test…) to each person. This is learning personalized process and system which supports such process was called Adaptive Learning System.

Therefore, learning adaptive system is able to change its action to provide both learning content and pedagogic environment/method for student. Adaptive systems base on the "description of learner's properties" called learner model. The process which gathers information to build up learner model and update it was named: learner modeling. Adaptive system tunes learning material & teaching method to learner model. However, learner model is focused in this paper.

***Keywords*—**learner model, user model, adaptive learning, learning management system, learning object, adaptive educational hypermedia system.

***Note*—**User model, student model and learner model are synonymic terms in this paper because users are regarded as learners or students in learning context.

I. Introduction

THE terminologies: user model and user profile are often used interchangeably but they have slight difference. A profile contains personal information without inferring or interpreting. User model has a higher level than profile, expresses abstract overview of learner. Moreover, it is able to deduce more extra information about learner from model. User model is often applied in special domain.

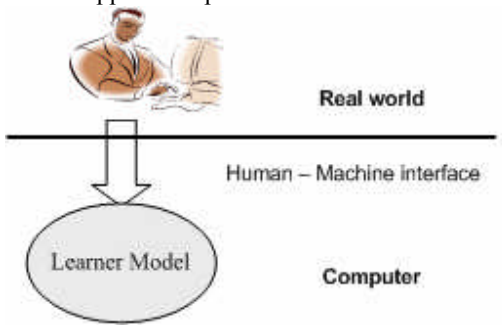

Fig. 1 Learner modeling

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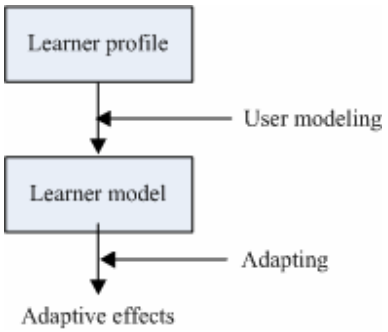

Fig. 2 Learner profile & model in adaptation

Hereafter, there are sections which will be presented:

Section 2: First, should glance over adaptive learning system.

Section 3: Description of learner's essential features and classification of learner models.

Section 4: Conclusion.

II. Adaptive Learning System

As we know that our environment is very complex and everyone has individual characteristics. Learners are not the same "size" (physically and mentally). Moreover, user's preferences are various. So, adaptation become imperative, especially in education. The most popular adaptive learning system supporting personalized learning environment is **AEHS** (**A**daptive **E**ducation **H**ypermedia **S**ystem). Here, AEHS is regarded as a example for illustrating prominent traits of adaptive learning system.

This paper discuss about learner model but our research intend to apply learner model to AEHS. So, we only introduce some basic aspects of AEHS. As agreed in abstract, adaptation is ability to change system's behaviors to tune with learner model. Hypermedia is the combination of hypertext and multimedia. AEHS can be know as the system providing learner with learning material in form of hypertext and multimedia (like hyper book, electronic book…) tailored to learner's preference. According to [7], there are two forms of adaptation: adaptive presentation and adaptive navigation:

- *Adaptive presentation* refers to the information which is show, in other word, what is shown to the user.
- *Adaptive navigation* refers to manipulation of the links, thereby; the user can navigate through in hypermedia. In other word, it is where user can go.

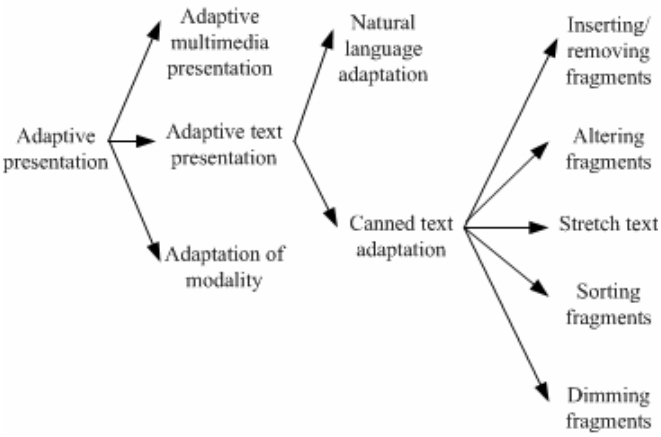

Fig. 3 Adaptive presentation

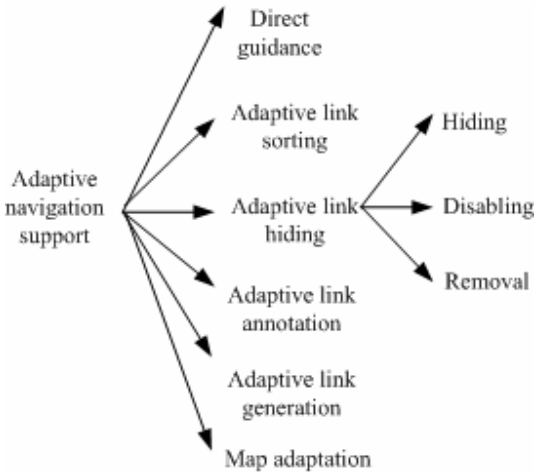

Fig. 4 Adaptive navigation

In general, the architecture of AEHS has two layers: *runtime layer* and *storage layer*. Runtime layer has responsibility for presenting adaptive learning material to user and observing user in order to update learner model. Storage layer is the main engine which controls adaptive process with some tasks such as:

- Initialize and update learner model.
- Choose concepts in domain model, educational resource in Media Space by selection rules.
- Store learning resources, domain ontology, learner model…

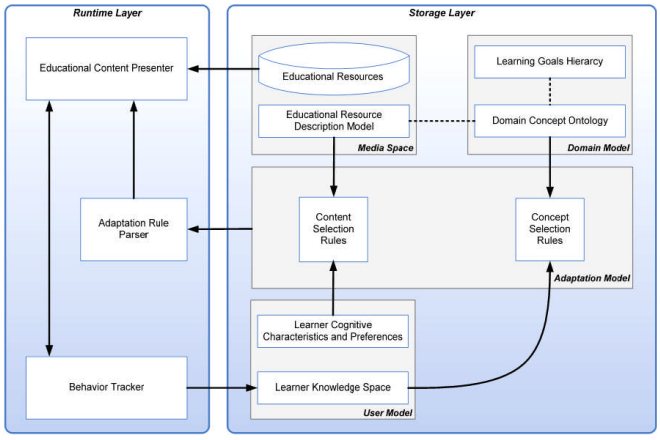

Fig. 5 General architecture of AEHS

As we see in architecture of AEHS [14], storage layer has four models:

- *Media model*: contains learning resource and associated descriptive information (metadata).
- *Domain model*: constitutes the structure of domain knowledge. Domain model was often shown in the form of graph. Nowadays, researchers intend to build domain model according to ontology.
- *Adaptation model*: is the centric component which gives effect to adaptation. It contains content selection rules and concept selection rules. We apply content selection rules to choosing suitable educational resource from medial model. On the other hand, concept selection rules are used to choose appropriate concept from domain model. These rules must obey user model so that the selection gets correct.
- *User Model*: information and data about user. User model will be described in detailed (see section III).

III. Learner Model

A. Information in learner model

User model must contain important information about user such as: domain knowledge, learning performance, interests, preference, goal, tasks, background, personal traits (learning style, aptitude…), environment (context of work) and other useful features.

[6] stated that content of user model can be divided into two categories: domain specific information and domain independent information.

Domain specific information

This information reflects the status and degree of knowledge and skills which student achieved in certain subject, major. Domain specific information is organized as knowledge model. Knowledge model has many elements (concept, topic, subject…) which student needs to learn. Knowledge model can be created by some ways which result many forms. Some widespread forms will be introduced below:

- *Vector model*. Learner's knowledge in domain was modeled in a vector. This vector consists of concepts or topics or subjects in domain. Each element of vector which is a real number or integer number (range within an

interval) shows the degree which learner gains knowledge about those concepts, topics or subjects. Vector model is simplest but very effective.

- *Overlay model*. Learner's knowledge is the subset of expertise's knowledge. Similar to vector model, each element in overlay model is the number which presents learner's knowledge level (see more in section III.B).
- *Fault model*. The drawback of vector model and overlay model is that it can not describe the lack of learner's knowledge. Fault model can contain learner's errors or bugs and what reasons learners have these errors. Taking out information from fault model, adaptive system can deliver learning material, concepts, subjects or topics that users don't know. Adaptive systems can also give users explanations, annotation to know accurately them or provide users guidance to correct errors.

Besides essential information about domain, there was extra information stored in learner model, such as:

- Prior knowledge of learner.
- Records of learning performance, evaluation…

Domain Independent Information

Besides information about knowledge, domain independence information may include: goals, interests, background and experience, individual traits, aptitudes and demographic information.

- *Interests*. Interest is particularly essential in commercial recommendation system. It is also important in adaptive educational system.
- *Goals*. In most cases, goal expresses learner's purpose, in other words; it is an answer for the question what learners want to achieve in learning course. There are two kinds of goal: long-term and short-term. Long-term goal is relatively permanent in course. Moreover, learner can propose themselves long-term plans for lifelong study. By short-term goal, learner intends to solve certain problem such as: passing an examination, doing exercise… Short-term goal was also called as problem-solving goal.
- *Background* and *experience*. Background includes skills, knowledge that learner gained in the past. Such information affects adaptive process. For example, if student experiences hardships in previous courses then AEHS should deliver high level exercises to him/her.
- *Personal traits*. Personal traits are user's characteristics which together define a learner as an individual. Two basic personal traits are *learning styles* and *aptitudes.*
  - Learning styles were defined as the way learner prefers to study. Table below shows some common learning styles:

TABLE I
LEARNING STYLES

Learning styles	Description
Auditory	Prefer to listen to instructional content
Pictures	Prefer to perceive learning material as pictures
Text	Prefer to perceive learning material as text
Tactile Kinesthetic	Prefer to interact physically with learning material such as: puzzles, games
Internal Kinesthetic	Prefer to make connections (to personal and to past learning experiences)
Auditory	Prefer to listen to instructional content
Pictures	Prefer to perceive learning material as pictures

According learning style, learners can be divided into some groups:

TABLE II
GROUP

Group	Description
Activist	Like to have a go and see what happens
Reflector	Like to gather information and mull things over
Pragmatists	Prefer to perceive learning material as text
Theorist	Like tried and tested techniques which are relevant to my problems

  - There are eight forms of aptitudes: linguistic, logical/mathematical, spatial, kinesthetic, musical, interpersonal, intrapersonal, naturalist.

TABLE III
APTITUDES

Aptitudes	Description
Linguistic	competence to use language
Logical/mathematical	competence to use reason, number and logic
Spatial	competence to perceive the visual
Kinesthetic	competence to handle objects skillfully
Musical	competence to create and compose music
Interpersonal	competence to communicate with other person
Intrapersonal	competence to self-reflect
Naturalist	competence to realize flora and fauna

However, for me, aptitudes are learner's features not used usually in adaptive process because they are too complex and unpractical to implement in software engineering. Learning styles are more important than aptitudes.

- *Demographic information*. Demographic data includes name, birth day, sex, ID card… In general, demographic information is used to identify person.

B. Classification of learner models

Stereotype model

Stereotype [30] is a set of user's frequent characteristics. New learner will be classified according to their initial features, each classifier is stereotype. By small amount of information in stereotype, it is able to infer much more new assumptions about user. If information about user is gained in detailed and concretely, assumptions will be changed to become more precise. The term "assumption" refers the system's belief about user but this belief is not totally reliable, just temporary.

In general, stereotype represents a category or group of learners. There are two kinds of stereotype: *fix* and *default*.

In fix stereotype, learner is assigned to predefined stereotype at abstract level. For example: in Java tutorial course, students are divided into five group, corresponding to five level, each level is more difficult than previous level: novice, begin, known, advanced & expert. After obtaining individual information such as: former knowledge, experience… system will assign each student to one of five levels and never change.

In default stereotype, it is more flexible. Therefore, first, learner is assigned to the initial stereotype. It means that initial stereotype has "default" value. System will observe students and gather their performance data, actions, results of tests… in learning process. Finally, system changes the initial stereotype to new more appropriate stereotype. Straightforward, the setting of stereotype is gradually replaced by more precisely and is more fit to learner.

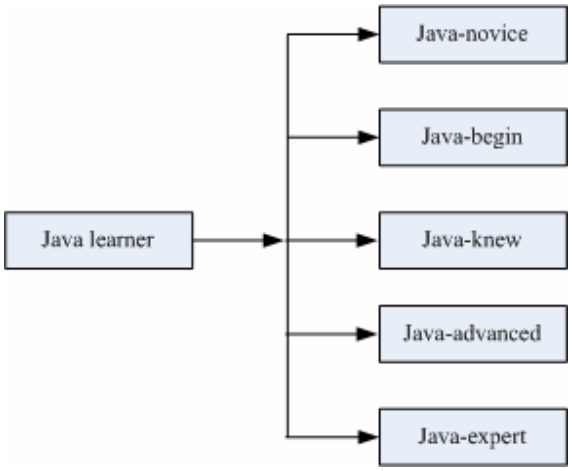

Fig. 6 Stereotypes

There are three important components in a stereotype: trigger, inference and retraction:

- *Trigger* is used to active a stereotype. In other word, it is a condition (e.g. logic expression) to assign a stereotype to learner. For example: if trigger "don't know Java" is activated, the stereotype "Java-novice" will be assigned to learner.
- *Inference* is inferring engine, responsible for deducing related information about user from stereotype. For example: if learner is glued to "Java-expert" stereotype, inference engine should take out both essential and extra information such as: learner knows object-oriented programming, interface, swing, internationalization problem, Java pattern…
- *Retraction* conditions are used to deactivate learner's stereotype. There is a circumstance: student was assigned stereotype "Java-novice" at the beginning of course but after learning process, student knew thoroughly Java, so his stereotype "Java-novice" is no longer suitable. Event "Users do final Java test very well" is condition to retract his stereotype "Java-novice" and he will be assigned a new appropriate stereotype – "Java-expert".

Overlay Model

The essential idea of overlay modeling is that the learner model is the subset of domain model. In other word, the user overlay model is the shot of comprehensive domain model. Domain model is constituted by a set of knowledge elements representing expertise's knowledge, normally; each element represents a concept, subject or topic in the major. So, the structure of user model "imitates" the structure of domain model. However, each element in user model (corresponding to each element in domain model) has a specific value measuring the user's knowledge about that element. This value is considered as the mastery of domain element ranging with certain interval.

Straightforward, the domain is decomposed into a set of elements and the overlay model (namely, user model) is simply a set of masteries over those elements. Suppose that the mastery of each element varies from 0 (*not mastered*) to 1 (*mastered*). Then the expert model is the overlay with 1 for each element and the learner model is the overlay with at most 1 for each element.

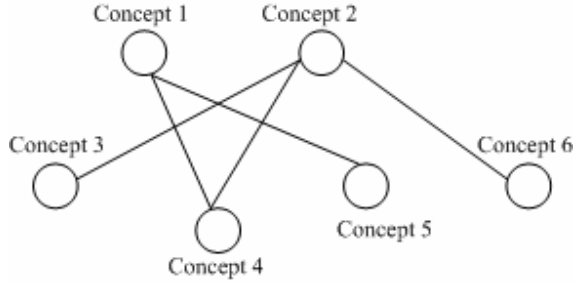

Fig. 7 Overlay model

Overlay modeling approach was based on domain models which are often constructed as knowledge network or knowledge hierarchical tree. Authors, experts have responsibility for creating domain model. Normally, each concept in domain model is mapped to learning object. Nowadays, there is trend to build up domain model by ontology.

Differential model

Overlay model was based on expert's domain knowledge but there is need for learner/teacher to suppose the knowledge which is necessary to learner. That knowledge was called *expected knowledge*. In other word, expected knowledge is domain knowledge that learner should be mastered at the certain time.

Therefore, differential model is basically an overlay on expected knowledge, which in turn is an overlay on expert's domain knowledge. With the overview of top-down methodology, differential model is a variant of overlay model. But in detailed, the differential model is instance of the class "fault model" (see section III.A) because expected knowledge can be considered as the knowledge that user lacks.

Perturbation model

Both overlay model and differential model presume that learner's knowledge is the subset of expertise's knowledge. They are not interested in learner's errors caused by

misconceptions or lack of knowledge. These errors were considered as *mal-knowledge* or incorrect beliefs.

Perturbation model represents learners as the subset of expert's knowledge (like overlay model) plus their mal-knowledge. Hence perturbation model is also instance of the class "fault model". This model open up new trend of modeling, so it can support better for adaptive system.

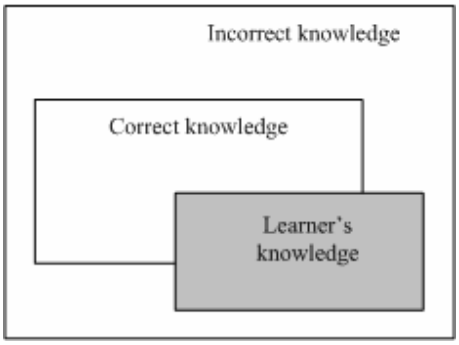

Fig. 8 Perturbation model adds incorrect knowledge to subset of expertise's knowledge

Plan Model

Plan is a sequence of learners' actions to achieve desires or concrete goals. Plan recognition was based on tracking input user's performance [22]. There is the library consisting of all possible plans. User's actions are regarded and matched to these plans. The plan which is most similar to user's actions is chosen as learner model. This is plan recognition process. In this approach, it is very expensive to create library and requires complex computation & large storage. Furthermore, matching algorithm needs careful implementation and spends much time in executing.

IV. Conclusion

User model has extremely important role in most user-oriented system, especially, adaptive learning system. It is not easy to classify learner models and methods of modeling but useful learner models were supposed in section III.B. However, we believe that building up the learner model must follow three below steps:

- *Initialization* is the first step in user modeling. It gathers information and data about user and it constructs user model from this information. Initialization process also determines structure of user model, reasoning method, storage of user model. There are two common ways to gain data about user so that system can initialize user model: explicit questions and initial tests.
- *Updating* intends to keep user model up-to-date. System can observe user's actions, track user's performance, and analyze user's feedback. Those tasks were done implicitly or explicitly.
- *Reasoning* new information about user out from available data in user model.

Reasoning is complicated but most interesting and so, research about learner modeling is ongoing.

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