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A Proposal of a Complete Ontology Modeling the Learner Profile to Integrate into Adaptive Hypermedia Systems

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Abstract: This study joins our work done on the development of adaptive learning systems and precisely the design of the learner model that represents the relevant information about the knowledge and the behavior of a learner during his learning phase. Given the diversity of learner information and design techniques, the proposals of existing learner models in literature differ and do not individually imply all dimensions of relevant elements of learners. In fact, we will try in this study to propose a complete learner model that includes all dimensions of the learner. These dimensions or facets are collected from different existing proposals that will be presented and discussed in detail by following a plan that starts with a presentation of the state of art, then a comparative and critical study and finally, ends with a presentation of all the design proposals for the different dimensions and facets that make up our proposed learner model.

Key words: Adaptive learning system, learner model, learner profile, Munich, knowledge, e-Learning, competency, emotion, cognitive ability

INTRODUCTION

Nowadays, the technological revolution and the internet are constantly affecting and changing our way of life. And this concerns all areas including learning. Indeed with the increase in the world's population, people are more interested in learning and seeking for information anywhere and anytime. Unfortunately, this can not be offered by the classical learning methods of universities and colleges. As a result, the era of distance learning using internet 'e-Learning' has emerged to offer flexibility in terms of time and place where learning can be done at the learner's home and courses can have a flexible learning schedule.

Given the success of the e-Learning, several approaches and learning system has been developed and can be grouped in two categories. The first category is the classical learning systems such as Learning Management Systems (LMS) (Watson and Watson, 2007) and Massive Open Online Course (MOOC) (Hollands and Tirthali, 2014). These systems are mainly characterized by providing the same learning content in the same form and presentation to all learners despite their differences in terms of preferences and objectives.

While the second category refers to the new learning systems called 'adaptive learning systems' that have emerged in response to the first category by offering the ability to adapt and adjust the learning content to preferences and needs of each learner.

Since, the adaptation is the main property of these new systems, it is essential to integrate into these systems a model called learner model or learner profile that provides a complete and faithful description of all aspects of the conduct and behaviorof the learner during his learning phases.

Indeed, we have found in literature several learner model propositions that, we have carefully studied and compared. And after several analyses and studies, we first selected the relevant elements and strengths of each of the existing proposals and then conducted extensive research on these selected elements to build our own learner model composed of six facet which are: personal data, competency and knowledge, learning styles/preferences, historic, cognitive ability and emotional state.

So in the following sections of this study, we will first present all the approaches and existing learner model proposals found in literature. Secondly, we will make a comparative and critical studies of these approaches. And finally, we will introduce our proposition of the learner model based on six facets. This facets will be the subject of deep studies that, we used to design models for each facet using UML2 class diagram.

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MATERIALS AND METHODS

State of art; Existing learner model: As mentioned in the introduction, we will in this section introduce all the learner model proposal found in literature.

Approach proposed by Carchiolo *et al.* (2007): The first approach that, we studied is the model proposed by Carchiolo *et al.* (2007) this approach gathers all the information of a learner during his learning phase in a triplet {GI, CI, SI}. Where, 'GI: General Information' refers to general and learner-specific information, 'CI: Course Information' represents course-specific information and finally, 'SI: Session Information' dedicated to session-specific information. In fact, the two components 'CI' and 'SI' have been excluded from our studies because they are not really part of the learner model. Given the variety of information that the 'GI' component includes, Carchiolo *et al.* (2007) have broken it down into four subgroups. Which are:

- SPD-personal data: contains all personal data about a learner. In general, this data is not related to any topic. Such as: his name, age, gender and his address, etc
- MS-media appropriate for the learner: represents all the media that is appropriate for the student (for example, a blind learner can not use any visual aids)
- STK-knowledge: encompasses all of the learner's knowledge. This knowledge is either provided manually by the student during registration in the system or obtained through admission tests
- H-historic: keeps track of all the actions performed by the learner during his learning phase. Namely: test results, authentication dates, etc

Approach proposed by 'Amel Behaz, Mahieddine Djoudi': The second approach was proposed by 'Amel Behaz *et al.*' and it is composed of four facets shown in Fig. 1. These four facets are the result of work done by the researchers on cognitive theories for the description of learner profiles and more specifically on the representation of learning styles. In the following, we present descriptions for each of these four facets:

IdentiUser: This facet is responsible for representing the general information of a learner and is modeled as a set of "Attribute-value" pairs. Let's take a concrete example of the learner 'A1', this learner will be represented as follows: <A1, <Name, 'TMIMI'>, <language, {'Arabic', 'French', 'English'} >, <Age, '27'>, <Gender, 'Male'>>.

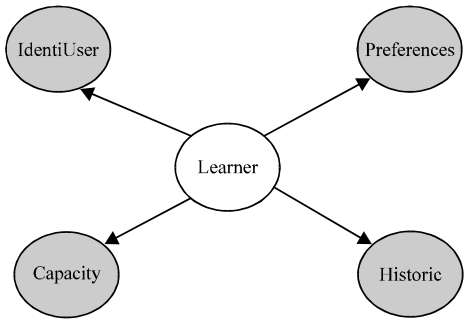

Fig. 1: Learner model proposal by 'Amel Behaz, Mahieddine Djoudi'

Preferences: This facet represents the learning preferences of learners. This component is based on the theory of psychological types of MBTI "Myres-Briggs Type Indicator".

Capacity: This facet represents the level of learner knowledge for a concept. This level is modeled by a stereotype system that refers to a class of individuals that re supposed to have the same level of knowledge. In practice, learners are taken to a multiple choice test. And according to their results, they will be assigned to a class (stereotype) that contained several adaptations methods already elaborated and optimized for this class. The possible values for the QCM tests are: low, medium, excellent. The choice of this scale of note was developed by the researchers in order to have the minimum necessary precision without going deep into the details.

Historic: This facet is supposed to contain all the traces of the learner's actions. Namely: the courses read, the tests performed, the dates of authentications, etc. All this information will be logged according to a key-value system. Here, is an example proposed by the researchers: the history of the learner A1 is described by <A1, <"HTML5", "Introduction", "11/05/2019">, <" HTML5", "you first web page", "20/05/2019">>

Approach proposed by 'DesislavaPaneva-Marinova' Paneva (2006): In contrast to the two approaches mentioned earlier, Desislava P.'s approach divided learner's information into two main groups. The first group concerns general information about learners such as: factual and historical data (personal information), learning objectives, cognitive skills, motivations, preferences, etc. While the second group focuses on the learners behavior during their learning activities such as: the general level of competence for the course, the skill level of the module, the skill level of the concept, the

Table 1: Descriptive of the general information of the learner

General information of the learner	
Element	Description
Factual and historical facts about a learner	His name, date of birth, gender, email address, phone, etc
Learning objectives	Contains the objectives and the goals achieved by a learner
Motivations	This element contains measurement of a set of parameters associated to a learner. Such as: motivation, effort, attention, interest, distraction, persistence and so on
Experiences	All the previous experiences will be reported in this element and will be used in future instructional strategies and adaptive methods
Preferences	The preferences of a learner can be managed using one of the learning style theories. Desislava P. and al. Chose to implement it using the Gardner's theory of learning styles

Table 2: Descriptive of the information about the learner's behavior

Information about the learner's behavior	
Element	Description
Conceptual skill level	Determines whether the concept has been mastered by the learner or not
Module proficiency level	Indicates the state of the module for a learner the researchers have specified cing states which are: not ready, ready, visited, learned, mastered
Global skill level for the course	Describes the initial state of mastery of the course by a learner. The possible values are: beginner, intermediate and advanced
Test resolution status	All the statuses of the test results passed by the learner will be reported by this element. The researchers have defined six statuses: learned, unresolved but studied, resolved, solved with hint help, solution failed or investigated

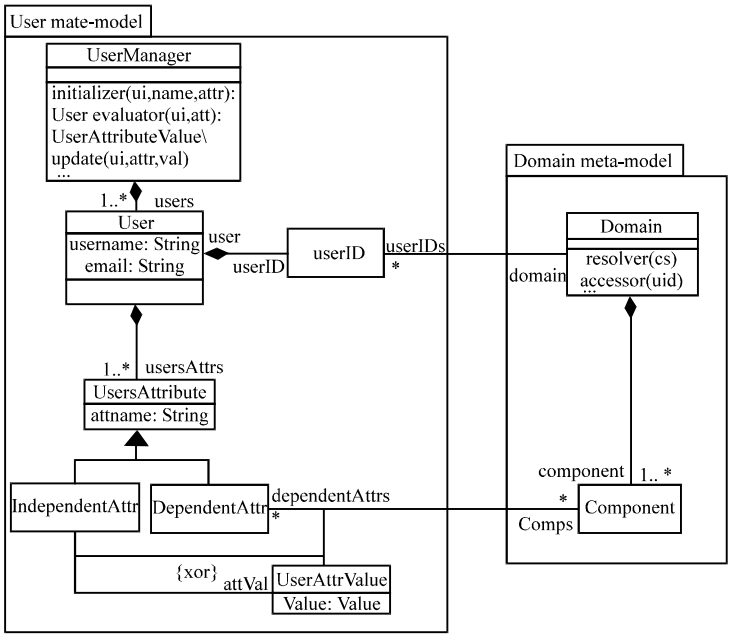

Fig. 2: View of the user meta-model of the Munich reference model

duration module study, test resolution status, etc. In Table 1 and 2, we present a detailed explanation of the components of the two groups proposed by Desislava P.

Learner model of Munich (Koch and Wirsing, 2002): The last learner model that, we studied is Munich. In fact, Munich is one of the famous reference models for adaptive hypermedia learning systems. Contrary to the approaches mentioned above, Munich does not propose a model but rather a meta-model characterized by a high level of abstraction using the object-oriented approach expressed by the class diagram of UML2 shown in Fig. 2.

In short, a learner is managed using a user class that contains its basic information. This class is linked through a composition association to the 'UserID' class which has the role of uniquely identifying the user in the context of the learning system. Each 'User-Learner' have a set of

objects of the 'UserAttribute' class. This set of objects provides a representation of user characteristics relevant to the learning system. The researchers of this model have verbally distinguished the different types of information that are supposed to be represents in the model. Namely: learner's knowledge, preferences, experiences, etc. and they summarized in two categories: "domain component information" and "learner general information".

The first group includes the domain-dependent attributes and is expressed using the 'DependentAttr class' while the second group;expressed using the 'IndependentAttr class' includes attributes that are independent of the domain and not related to components such as background knowledge and preferences.

Comparative and critical studies: All of the approaches and models studied previously reflect each in his own way and his vision an important set of information about the learner. We distinguished two groups of learner information:

The first group concerns the approaches that have divided learner information into facets or dimensions representing semantically related types of information. These facets include: general information, knowledge, Preferences and historic. Each approach of this group has its own ways of elaborating its facets in the sense where there are some who have used conceptual vectors, others have chosen a modeling language like UML2. Also, we noticed a diversity in terms of the choices for implementing some facets. For example, in the preferences facet, some used Gardner theory of psychological profiles while others used the MBTI.

The second group concerns approach that have not concretely defined learner information. This group of approach have just introduced the general information of the learner (name, first name, etc.) and managed the rest of the information by means of couplets 'attribute: value'. We have judged this way of managing learner's information by means of couplets 'attribute: value' not relevant. Because it has a major disadvantage that lies in the lack of semantics. Indeed, according to the semantics of each information of a learner, strategies of adaptation processes will be realized.

Also, we have found in literature other types of information that have not been introduced into the approaches presented previously and which have an influence on the learning process. To know:

Cognitive skills that describe a learner's abilities regarding specialized treatments such as vision, space, language, gestures, coordination, attention, memory and strategies. Emotional state that describes the emotional state of the learner, i.e., the degree of learner motivation, self-control, etc.

Finally, we would like to present a theoretical model named LMPA123 that can be exploited to extend the set of learning approaches and models mentioned above. Indeed, the LMPA123 Model is not a learning model but an extension of any existing learning model in the context of adaptation. This model has three levels:

Level 3: At this level, it is necessary to specify the basic elements of the profile necessary to constitute all the learner profiles. This level is achieved by the researchers and is at a very high level of abstraction, i.e., it does not contain relative or relative disciplinary information at a given grade level.

Level 2: Represents the learning models adapted to a given field. In other words, this level is only a selection of the elements introduced at "Level 3" by a pedagogical designer who take into consideration the specification of needs for a given field or context.

Level 1: This level contains the instantiations of the "Level 2" profile model with concrete data from a learner. This level represents a model of the state of knowledge of a given learner in a given context and at a given moment.

RESULTS AND DISCUSSION

Our proposal: Our learner model proposal is composed of six facets (Fig. 3). which are: personal information, knowledge and competency, historic, psychological profile, cognitive skills and emotional state. These facets hold all the useful information about the learner to be used for different process in his learning phase.

These six facets have been the subject of different studies that, we have done in order to have as much information as possible to design them. In what follows, we will present the six facets of our model as well as the related works that, we have chosen to implement and finally, we will introduce for each facetits design proposal using the UML2 class diagram.

Personal data facet: This facet contains the personal data of the learner, namely his identity, gender, age, etc. and it was designed by a set of properties belonging to a learner. In Fig. 4, we show the UML2 class diagram.

Competency and knowledge facet: This facet will contain the knowledge, skills and competency acquired by a learner. Such as: internships, diplomas, certificate and so on. To design this facet, we used the work done on the competency based learning approach. This approach is

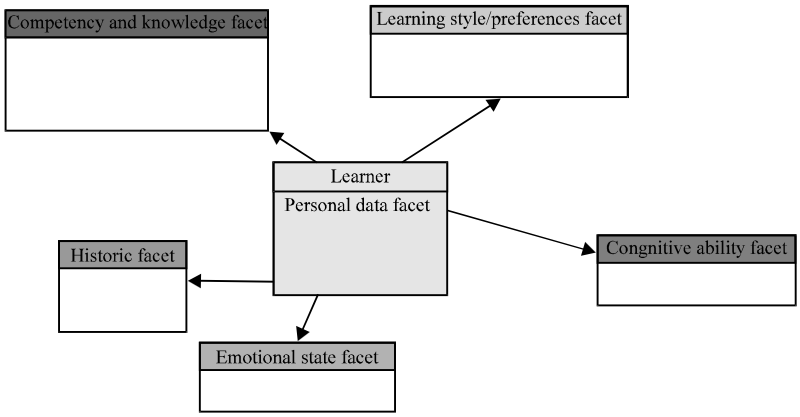

Fig. 3: Our global learner model proposal

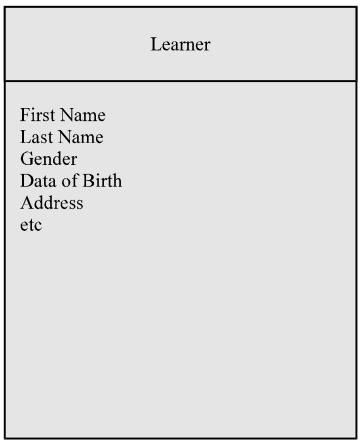

Fig. 4: UML2 class diagram of the personal data facet

built around the competency and aims to solve many problems in particular the mismatch between school education and the needs of the labor market, the improvement of professional performances, the overpopulation of class, etc.

Among the works that, we have studied, we cite the paper written by Hachmoud *et al.* (2017) that proposed a conception of the competency approach and used it to model the competency facet shown in Fig. 5.

Historic: This facet is responsible for keeping track of all actions performed by the learner including course reads, authentication frequency and so on. To model this facet, we used in Fig. 6 a basic method which consists in storing all types of transactions (actions) made by the learner in a set of insert, delete, update and select requests.

Preferences/learning styles: In this facet, we will manage the preferences of the learner in terms of the desired type of learning, the nature and size of the learning activities, the type of support desired, etc.

As, we mentioned in previous section, this facet is mainly based on the works done on the psychological profiles such as: Gardner's theory, MBTI and so on. So in our proposal, we chose the Felder-Silverman Learning Style Model (FSLSM) which combines the majority of the existing psychological profiles (Graf *et al.*, 2006).

Unlike other theories that classify learners into a few groups, the FSLSM Model is better suited for the learning context and describes in more detail the learning style of a learner. The FSLSM Model offers four dimensions that are: active/reflective, sensing/intuitive, visual/verbal, sequential/global. The theory assumes that each learner will have a value equal to 100% by adding the two poles of each dimension. Example: active 60%/reflective 40%-80%+20% = 100%).

In our proposal (Fig. 7), we have considered that each learner can have several psychological profiles but only the most recent one is taken into consideration for adaptation processes by the learning system. Each psychological profile has values for the two poles of each dimension. And finally, we added a set of preferences expressed by the two class (AffectedHandicap and PreferedLanguages) that describe the learner mastered languages and its physical limitations (handicap).

Cognitive ability: Cognitive abilities refer to all specialized treatments that require the collaboration of brain spaces. Namely: attention, memory and strategies, vision, language, gestures, coordination, etc. Despite the great importance of this facet, the previously mentioned approaches of the learning model did not introduce it into their models. Indeed, we have not found in literature many works that have discussed this subject in the context of adaptive hypermedia learning systems.

In our proposed learner model, we have been based on the referential proposed by Anon (2008). This

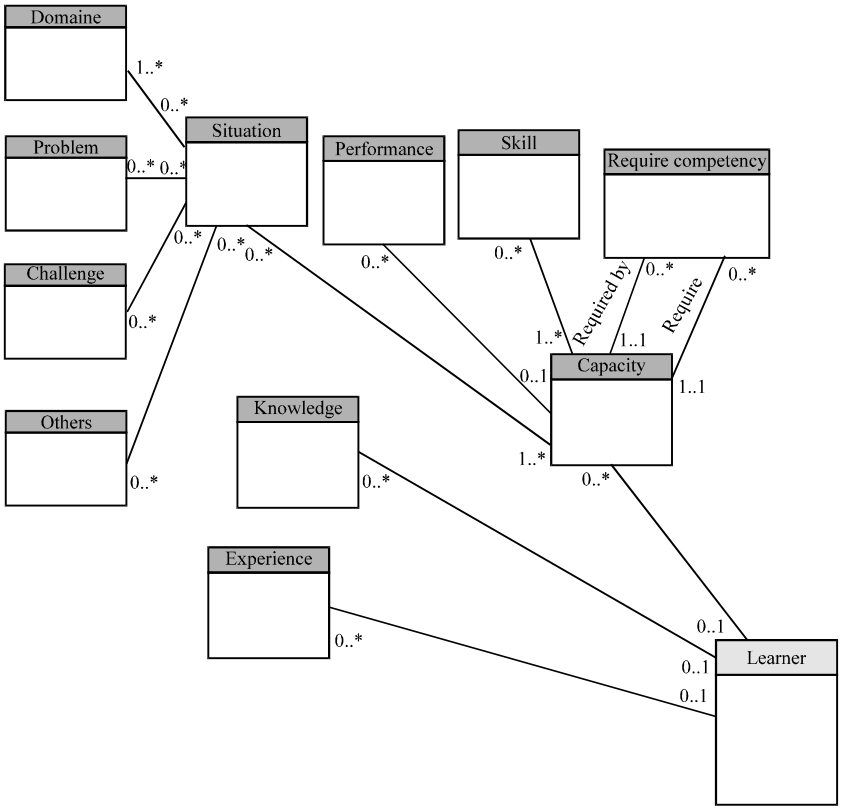

Fig. 5: UML2 class diagram of the competency and knowledge facet

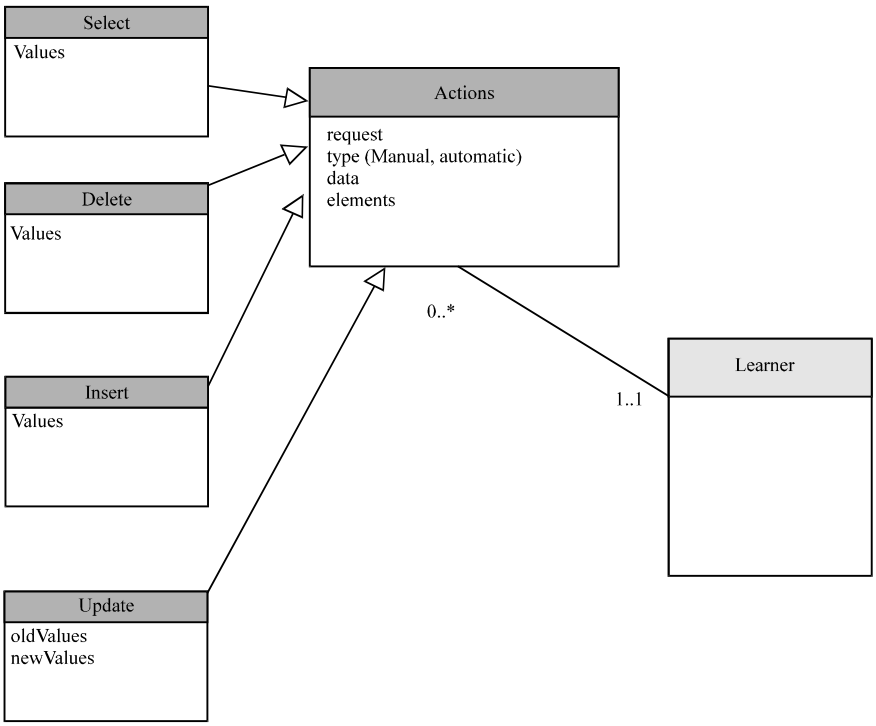

Fig. 6: UML2 class diagram of the historic facet

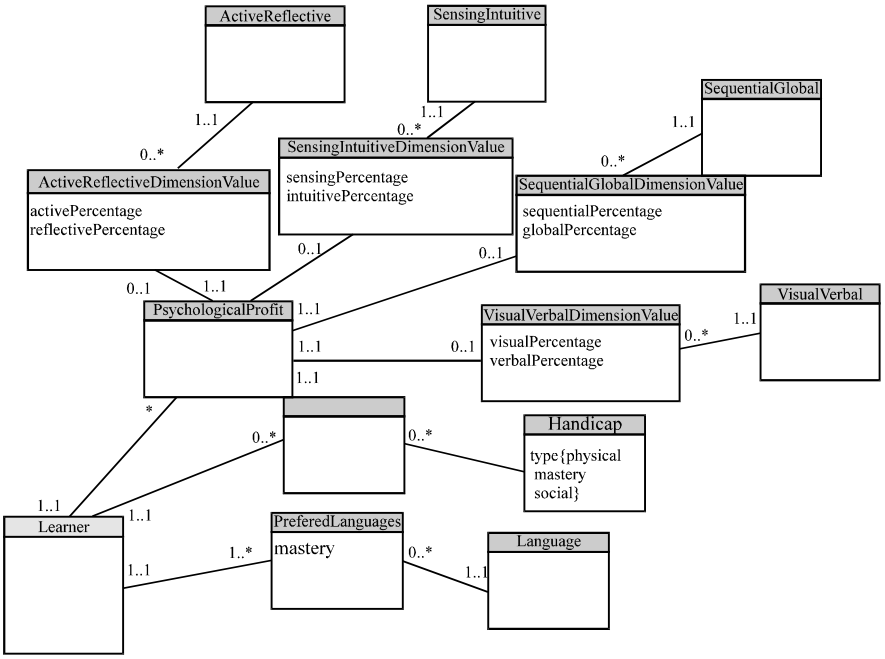

Fig. 7: UML2 class diagram of the preferences and learning styles facet

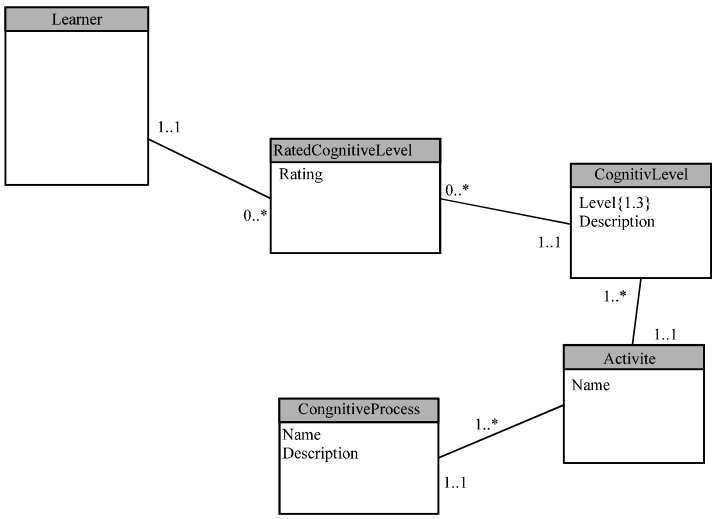

Fig. 8: UML2 class diagram of the cognitive ability facet

referential describes five cognitive processes which are: concentrate, memorize, communicate, know how to organize, search and process information. Each one of these cognitive process contains several levels on different elements. In Table 3, we show an example of the cognitive process "Memorize":

We are aware that all the process cognitive described by the Anon (2008) referential must be first adapted to the context of learning systems and be complemented by other process. It is for this reason that in our proposal for the cognitive ability facet (Fig. 8), we kept the hierarchy, expressed by the several levels for different elements of the cognitive process while making it abstract and open without specification or concretization.

Emotional state: The emotional state of the learner during his or her learning phases has a major impact on the success of knowledge acquisition (Rienties and Rivers, 2014). Indeed, we have studied several approaches that modeled emotion. namely: Russell Circumplex Model

Table 3: Descriptive of the cognitive process: 'Memorize'

	Memorize		
Cognitive process	Level 1	Level 2	Level 3
Memorization of activities	Learn by heart and restore in the same form what has been memorized	Memorize to restore in a different form, reformulate and give meaning	Ability to transfer or apply knowledge in a new situation
Short term memory	Some basic information	Several basic information	Several complex information
Duration of memorization	Short term	Average term	Long term
Mobilization of the senses	One of the five senses	Two or three senses	Mobilization to the five senses
Context	Calm	A little noisy	Noisy

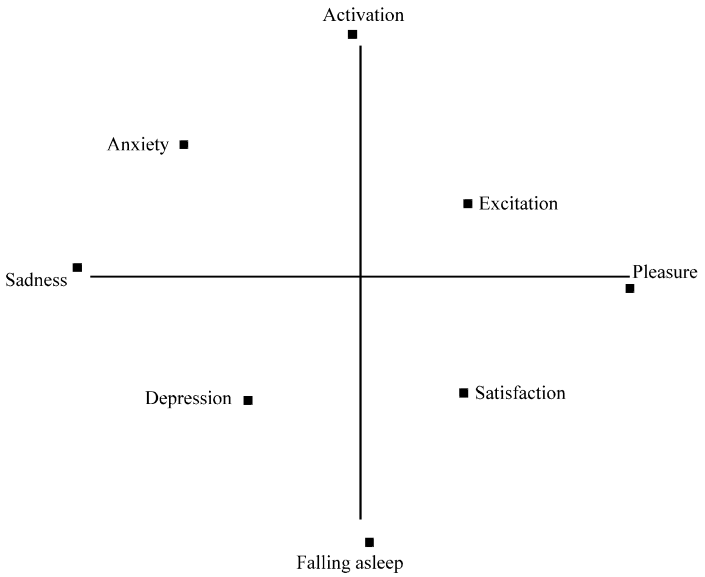

Fig. 9: Russel' s circumplex model (Russel, 1980)

(Russell, 1980), Kort Model (Kort *et al*., 2001). Each in its own way, the emotion is defined in a multidimensional space containing two dimensions.

In the Russell Circumplex Model, the two axes of multidimensional space are: valence and activation and they form eight diametrically opposite subspaces representing four pairs of opposite emotions (Fig. 9): Activation≠Sleep, Excitement≠Depression, Satisfaction≠ Anguish and Pleasure≠Sadness.

However, this approach is very general and abstract and is not adapted to the learning context. As a result, models of emotion modeling in relation to the context of learning have been developed. In particular, the Kort Model which proposes a theoretical model called "Four Quadrant Model (Fig. 10)". This theoretical model classifies the emotion using two axes:

- Vertical axis: this axis describes the difficulty of the learning situation, ranging from "Un-learning" to "constructive learning"
- Horizontal axis: this axis describes the valence of the emotion which varies depending on its effect (positive or negative)

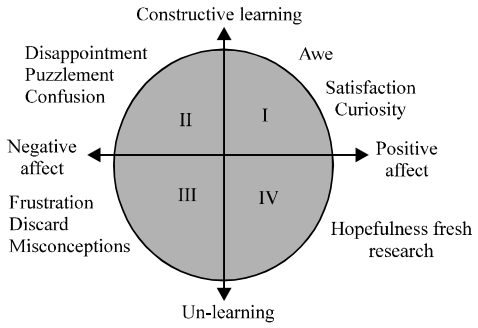

Fig. 10: Four-quadrant model of Kort *et al*. (2001) linking emotions in the learning phases

In our proposal (Fig. 11), we modeled the emotion using three dimensions these three dimensions are those of the model of Kort plus a third dimension named 'dimension of control or dominance' (Mehrabian, 1996). This new dimension describes the ability to control the situation that caused the emotion. Also, we have dissociated from emotion the judgment on the efficiency of learning. Indeed, we believe that negative emotion may

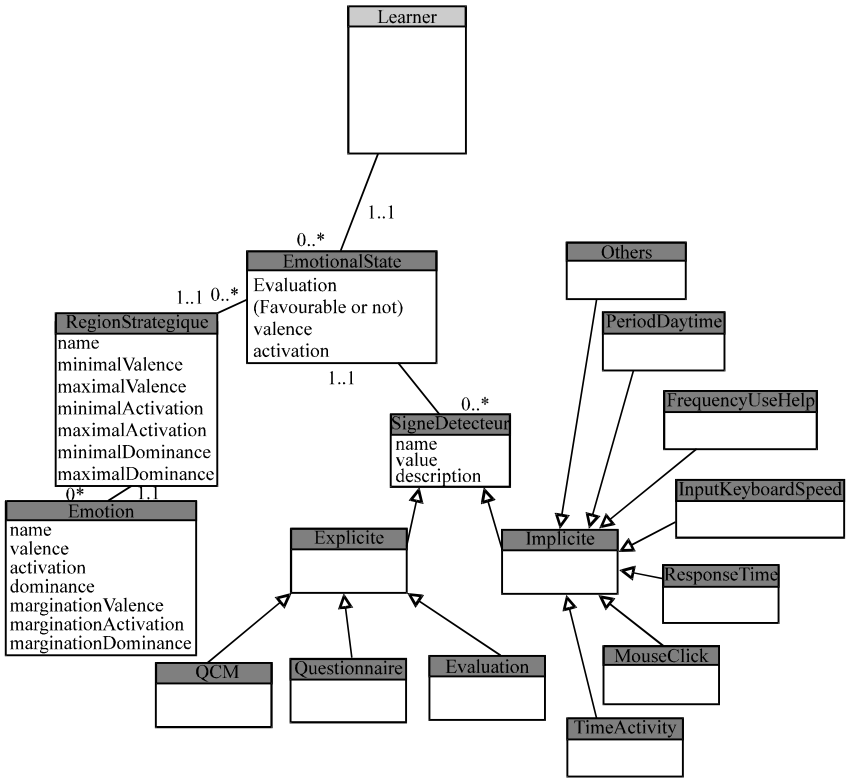

Fig. 11: UML2 class diagram of the emotional state facet

have a good impact on the acquisition of knowledge. Also, we associated to each detected emotion a set of implicit (Mouse Clicks, time spent on activity) and explicit (direct questions: QCM, Test, …,) collected variables from learner's behavior.

CONCLUSION

This study summarizes our research done in designing a new learner model based primarily on six facets. To do so, we began by presenting the state of the art. we then compared and criticized the existing models of the learner model and finally, we presented our proposal based on six facets that, we designed for each of them a UML2 class diagram. Certainly, we are aware that, we must always remain in search of new theories to be introduced on our model proposal in order to improve it and make it as relevant as possible while continuing the development of our learning adaptive hypermedia learning system in order to test in real experiments all our proposals.

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