Towards an Optimized Design of Individualized Learning Paths: an Approach Based on Ontology and Multi-agents System

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Abstract

In this paper we present an intelligent architecture, oriented goals, to create individualized learning paths. The adaptation of learning paths to learner profiles is an area of research growing. More research in this field has shown that taking into account the preferences and learning styles of learners improve the quality of the teaching/learning; thus, the collection of information characterizing learners as, for instance, preferences, learning styles, goals ... etc, and those characterizing learning resources (annotation of resources) are essential in order to make a matching between the query of learners and the profiles of hypermedia learning units.

To recover their learning style, the learner is asked to take a test based on the model of Felder and Silverman. This test tells us about cognitive characteristics and affective behaviors and psychological which serve as relatively stable indicators of how learners perceive, interact and react with learning environments.

Our contribution, therefore, consists of an adaptive approach based on semantic web, multi-agent systems and neural networks; thus, providing learners with personalized courses according to their profiles and their learning objectives.

Keywords: *e-Learning, Ontology, Multi-agent system, Neural network.*

1. INTRODUCTION

For many years, we were in logic-face learning, while we move increasingly to a logical distance learning. Distance learning offers training without spatio-temporal constraints. Several LCMS have been developed for this; however the majority of them apply the philosophy of "one-size-fits all" which means the same document is presented to all learners, so they do not have the same needs nor the same knowledge, nor the same learning styles ... etc. This is why the need for content adaptation is born.

The adaptation is to issue learners with learning paths tailored taking into consideration their goals and knowledge. The adaptation of learning paths to learners' profiles requires the collection of more information about learners and learning resources. In this paper, we present an intelligent architecture based on multi-agent paradigm, ontologies and neural networks to generate the personalized learning paths. We can summarize the objectives of this application in:

i. Offer customized courses.
ii. Encourage learner autonomy.
iii. Provide educational support to guide the learner to maintain its confidence.
iv. Make it possible for many learners to share the same learning experience.

The creation of the personalized learning paths is guided by predefined goals by the instructional designer, pre -tests for consumption and post-tests for the success of the goal.

These terms of input/output are determined by the creator of the Hypermedia Units, before publication, to meet effectively the needs of learner's consumers.

One of the most important information for the learner is the learning style. To communicate their learning styles, learners respond to a questionnaire of Felder and Silverman. It is composed of 44 forced-choice questions, each 11 questions are for four dimensions which are: "active-reflective", "sensing-intuitive", "visual-verbal", "sequential-global"[4].

Agent technology is used to design flexible solutions based on a stable set of agents that are in constant communication in order to accomplish the tasks assigned to them. In addition, we have adopted the techniques of the Semantic Web that rely primarily on semantic ontologies to describe learning resources. We will also use neural networks to create courses relevant remediation for learners who have not acquired all the concepts of the course generated.

In short, the proposed system will enable human agents (students, teachers and instructional designers) on the one hand, to cooperate with software agents to build a training relevant, and on the other, to allow the student to take support training at its option, either individually or in collaboration with others (students or tutors) based on classes of profiles of learners.

2. LEARNER MODEL

The learner model allows the system to adapt the learner interacts with it. That is to say, he has the knowledge to understand and use what the learner already knows. This can only be achieved through knowledge of the learner profile. This profile must include knowledge of the learner on the field, its educational objectives and learning style preferences.

To model the knowledge of the learner on the field, the most common knowledge representation paradigm of learning is the model layers. Its principle is that each concept of the domain model, is associated with an estimated value of knowledge of the learner on this concept. This estimate may be a binary value, a qualitative measure "well - meets - bad" or probability defining knowledge on the concept. The set of pairs "concept - value" is then the model layers;

The learner model contains also the classification type of physical media and preferred learning mode monitoring.

In the literature, several standards coexist, IMS, PAPI, IMS-LIP …etc. we have chosen the standard IMS-LIP [3,7,8,15], because it is the most suitable for our model. The standard IMS-LIP is based on a data model that describes the basic categories to record and manage the academic background, training objective and outcomes of learners.

2.1 Ontology Learners

Ontology is an explicit specification and formal concepts and their relationships. Ontologies are used in several areas of knowledge engineering, information retrieval, information extraction, management and organization of knowledge, e-commerce ... etc. The field of e-Learning does not derogate to the rule. To represent the profile of a learner we designed an ontology containing all the characteristics of learners namely: knowledge, goals, preferences, and learning style. The following figure provides an overview of the ontology of learners, edited by Protégé 2000, according to the standard IMS-LIP:

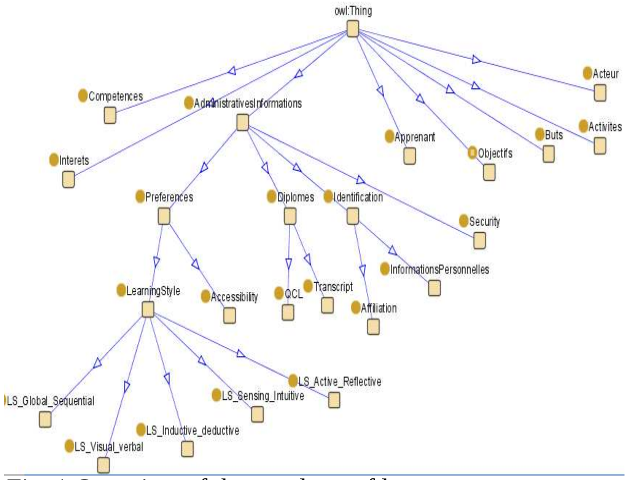

Fig. 1 Overview of the ontology of learners

2.2 Learning Styles

The learning styles is a topic that has sunk a lot of ink. Some learners may have difficulty grasping concepts that seem simple. It is likely that they have a different learning style of their teacher and his learning strategies are ineffective for them. Each learner has a way to learn as proper and all his own. Experimental research on the application of learning styles in online learning has shown that learning can be enhanced through the presentation of course materials that are compatible with the learning style of a learner.

In the last decade several models of learning styles are offered (Kolb 1984; Felder & Silverman 1988; Lawrence 1993 ... etc)[4].

In this article, we have adopted the model proposed by Felder and Silverman for the training of students in science and technology. The model will classify learners according to their way they perceive and process information. It is not a strict classification in the sense that a person of a particular type may, depending on the situation or need, cope with the methods of the opposite type. The Felder and Silverman model can classify learners according to 4 dimensions. Table 1 summarizes the psychological types depending on the model of Felder and Silverman.

Table 1: Learning style model Felder and Silverman

Learning Style	***characteristic***
Active/Reflective	**Active :** retain and understand information best by discussing it, applying it or explaining it to others; prefer group work; **Reflective:** retain and understand information best by thinking about it first; prefer working alone; needs thinking time during lectures.
Sensing/Intuitive	**Sensing :** like to learn facts; tend to be more practical and careful; do not like courses that have no apparent connection to the real world **Intuitive:** prefer discovering possibilities and relationships ; like innovation and dislike repetition; tend to work faster and are more innovative but may be careless
Visual/Verbal	Visual : remember best what they see, (e.g. pictures, diagrams, demonstrations); Verbal: gets more out of words, either written or spoken explanations.

Sequential/Global	**Sequential:** gain understanding in small sequential, logical steps; tend to follow logical stepwise paths while problem solving; may not understand material fully but are still able to solve problems and pass tests. **Global:** seem to learn in large jumps, absorbing material almost randomly without seeing connections, then suddenly "getting it"; may be able to solve complex problems quickly, or put things together in a novel way once they have grasped the big picture; may have difficulty in explaining their knowledge;

3. REPRESENTATION OF LEARNING RESOURCES

To design learning paths which are tailored to the profiles of learners, we decided to adopt the Pedagogy By Goals [5]. Students must submit their needs in the form of educational objectives which are the results they want to achieve at the end of their training. This requires fine structure concepts for optimal use. That is why we adopted the Pedagogy By Goals (PBG). PBG is a methodology that breaks up a teaching module in its complex and simple elements essential to facilitate the teaching/learning process and assessment. The decomposition is performed on the basis of educational objectives.

3.1 Structure of the Training Modules

Our architecture is based on the pedagogy by goals to structure the material to teach (i.e. the learning module). We use a three-level hierarchy of educational objectives as defined in [6]:

1. The General Objectives or abstract (**GO**);
2. The Specific Objectives or composite (**SO**);
3. The Operational Objectives or atomic (**OO**);

To classify these objectives, we opted for the taxonomy of cognitive domain by **Benjamin BLOOM**, who is the father of the first hierarchical classification of educational objectives. The taxonomy of educational objectives BLOOM [9], is composed of six levels, including: knowledge, comprehension, application, analysis, synthesis and evaluation. For each class, there is a set of verbs that can be used to express the objectives of Hypermedia Units.

This hierarchy has allowed us to consider three levels of abstraction module of instruction:

1. **Parts** (meeting the General Objectives);
2. **Chapters** (that meets the Specific Objectives);
3. **Hypermedia Unit of learning (HUL)** satisfying the operational objectives.

These are transfer credits evaluated. The system, then, organizes the process of education around these components hypermedia (the HUL). The HULs are supposed to receive, by instantiation, all kinds of domain knowledge in all forms of media permitted by HTML (text, image, sound, video, script, applet), Fig. 2 shows the structure of a module into simple elements.

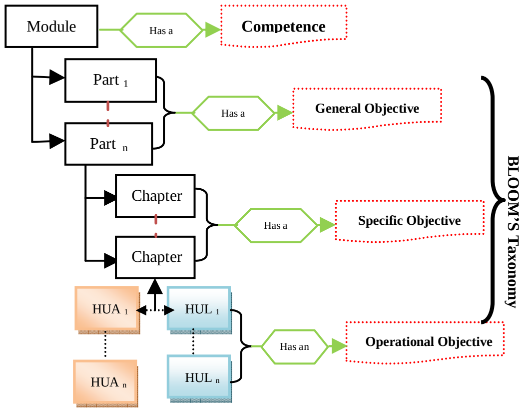

Fig. 2 Hierarchical representation of a module

The Hypermedia Units of Assessment HUAs serve to measure the achievement of operational objectives for the learner, and this, by pushing to do (do) by himself the application of management theory study.

Managements of HULs and HUAs in the canvas of tutor, is ensured by a system based on a multi-agent system and multi-ontologies,

The sequence of learning objectives (LOs) by the system is made on the basis of a "network of pre-requisites" proposed by the author of the teaching module. A prerequisite link between two objectives LO1 and LO2 (from LO1 to LO2) defines, on the one hand, a precedence desired by the author between the two objectives, proposing that learning the second objective cannot be completed until LO2 achievement (or success) of the first goal LO1, on the other hand, an indicative link of progression or a remediation of a potential link. This latter feature means that the system can choose a LO that is a pre-requisite to a LO on which the learner has failed in order to offer him a contribution of knowledge that relates to the LO prerequisites.

3.1 Hypermedia Unit

In this approach, we consider that a HU is a type of component with the properties of autonomy, reuse and sharing. A Hypermedia Unit description has a semantic that allows to specify the context in which we can reuse and the use that we can do. A Hypermedia Unit of Learning is a fragment of processes to achieve an educational objective. The notion of teaching objective is to define an appropriate use of a Hypermedia Unit (its purpose) but also to express variability. Indeed, the same objective can be achieved in different ways, depending on the learner profile, preferences…etc. The process dimension is another important aspect of Hypermedia Units. It can take into account the different teaching methods and strategies in defining learning paths.

Each Hypermedia Unit is characterized by a "profile" that describes the general appearance of Hypermedia Unit. It has an objective, background and way. It will be used when looking for a match between available Hypermedia units on the one hand, and intentions of learners, on the other.

For the representation of hypermedia units we have designed an ontology of resources, Fig.3 shows a part of the hierarchy class of this ontology, Fig.4 shows the characteristics of the Hypermedia Units and Fig.5 shows a part of the OWL code generated by the ontology. For indexing Hypermedia units, we studied several standards and finally the LOM [11] standard was chosen.

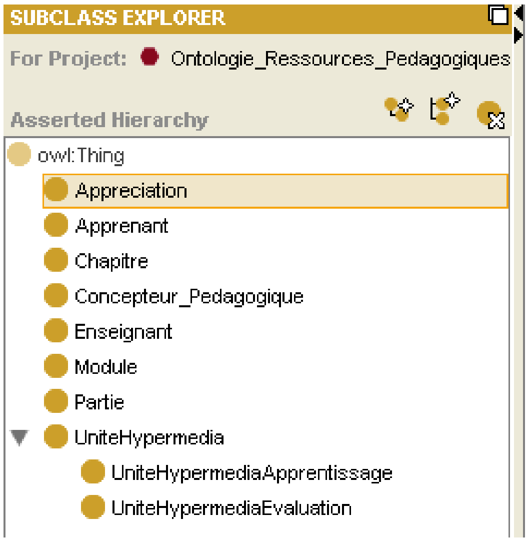

Fig. 3 View of the class hierarchy in the Resources Ontology

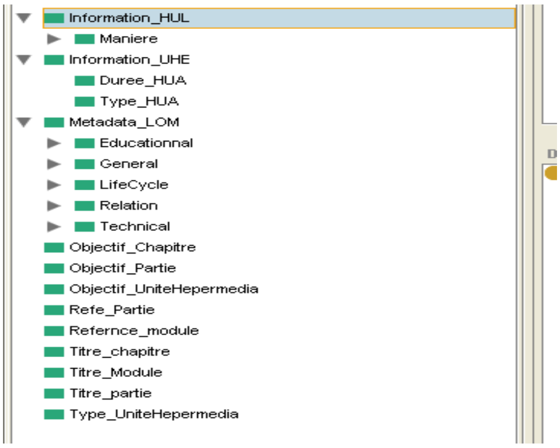

Fig. 4 Characteristics of Hypermedia Units

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<owl:DatatypeProperty rdf:about="http://www.owl-ontologies.com/Ressources_Ontology.owl#Contexte">
    <rdfs:subPropertyOf rdf:resource="http://www.owl-ontologies.com/Ressources_Ontology.owl#Educationnal"/>
  </owl:DatatypeProperty>
  <owl:DatatypeProperty rdf:about="http://www.owl-ontologies.com/Ressources_Ontology.owl#contribute">
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  </owl:DatatypeProperty>
  <owl:DatatypeProperty rdf:about="http://www.owl-ontologies.com/Ressources_Ontology.owl#Description">
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  </owl:DatatypeProperty>
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  </owl:DatatypeProperty>
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Fig. 5 A part of OWL code generated by Protege

4. DESIGNING COMPONENT ARCHITECTURE AGENT

Computing becomes more diffused and distributed. Decentralization and cooperation between software modules are needed to improve the quality of services of a system. In addition, with the growing size and complexity of new applications, the centralized vision seems has reached its limits. We are thus naturally led to seek a new way to give more autonomy and initiative in the various software entities. The concept of multi-agent systems (MAS) offers a response to these challenges. Currently multi-agent systems have addressed several areas, namely the field of education. They can contribute greatly to the improvement of the learning process.

4.1 Concept of Agent

Agent is called real or abstract entity that is capable of acting on itself and its environment, which has a partial presentation of this environment and, in a multi-agent can communicate with other agents which behavior, is the result of these observations, knowledge and interactions with other agents.

An intelligent agent operates in its environment and must be able to receive information and act according to an established behavior from observations and reasoning of other agents. Communication modules are essential, especially as the environment is with other agents which may cooperate to achieve its objective.

4.2 Communication Between Agents

The communication between agents is a primary property of Multi-Agent Systems (MAS) [10]. It increases the prospects of officers in their concurring in the benefits of information and know-how of other agents. The communication between agents is a fundamental means to ensure the distribution of tasks and coordination of actions between them. FIPA player in the field of SMA's main task is to develop a standard for communication between agents [20]. One of its achievement is the standard FIPA-ACL, there is another one which is KQML.

An Agent Communication Language (ACL) must be designed to exchange information between agents, knowledge or services. The ontology will provide specific vocabularies depending on scope for communication between agents and define the concepts and relationships that exist between the words of a formal vocabulary for the agents to use. Subsequently, the agents of a MAS share a common ontology (common vocabulary). Learners have a different styles, knowledge, and preferences of learning. The proposed architecture will resolve the problem of difference between learners through the creation of resources and optimal learning paths and customized to each learner. To improve the relevance of research Hypermedia Units, we propose in this paper an approach based on using ontology to classify targets in a hierarchical goals and an ontology of educational resources for document indexing, and use of semantic links between the Hypermedia Units of a journey, the ontology of the borrowed resources SCORM [21] which defines a tree structure representation. These ontologies are managed by a multi-agent system to generate custom learning paths. This model has the advantage of providing a mechanism of semantics between the profile of

Hypermedia Units and that of the learner to choose the "best" HU i.e. the HU most suitable both in terms of educational level and in terms of preferences (audio, video, language,...etc).

The system is designed so that each of its actors (teachers, learners and instructional designers) can accomplish their tasks: The teacher is the person responsible for the task of teaching and/or mentoring in a training process, he may also add to the pool system during all well-structured and annotated courses based on the ontology of educational resources which describes the structure of a course material. The learner seeks to acquire knowledge and understanding of knowledge in a particular area, and this by formulating an objective (general, specific or operational). As for the instructional designer, he collaborates in planning the whole course, and writes it. He offers relevant learning activities and ensures congruence between the objectives, content and evaluation. The diagram in Fig. 6 illustrates the actions of various entities of the system, and the Fig.7 is the zooming functionality of a Multi-agents System.

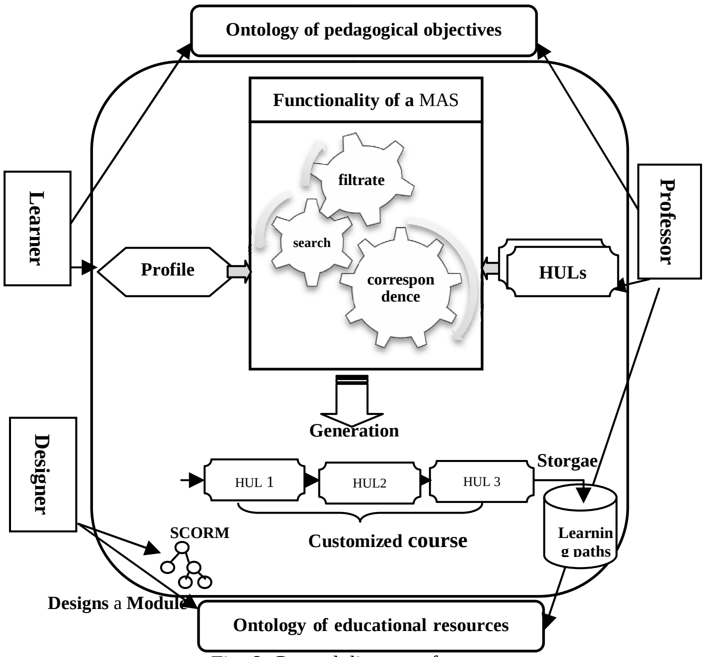

Fig. 6 General diagram of system

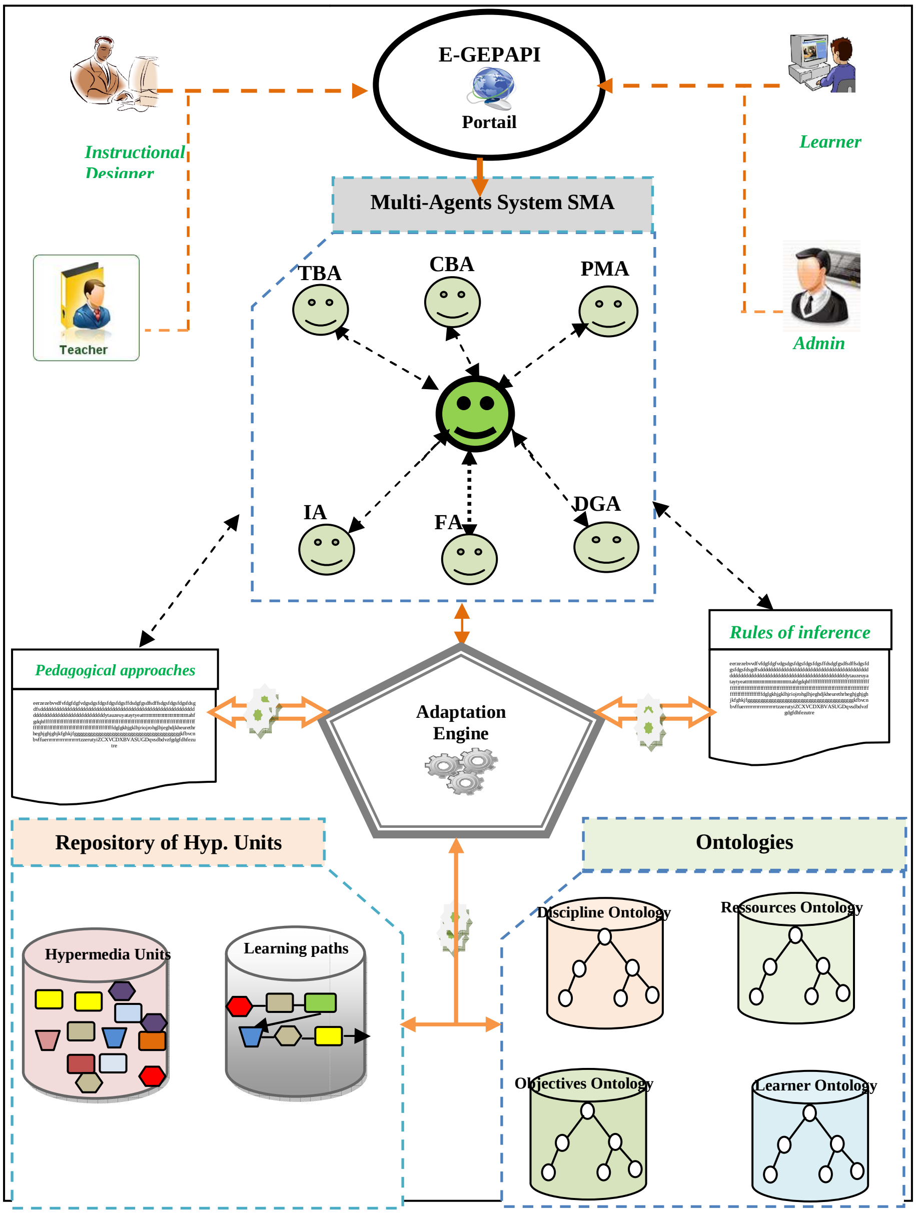

Fig. 7 Modeling of our Architecture based on MAS and Ontologies

4.3 The Multi-agents Architecture

The architecture we propose is based on flexible modules (agents) that allow interaction with the learner to offer training at its option. These agents are in permanent communication; it is managed by a manager agent. These agents can manage all parts of the architecture, coordinate the process, build personalized learning paths and perform testing of pre-conditions and post-conditions for each course. The proposed architecture is based on 7 agents (Figure 7):

- Interface Agent (IA);
- Manager Agent (MA);
- Contents Builder Agent (CBA);
- Tests Builder Agent (TBA);
- Profile Manager Agent (PMA);
- Filter Agent (FA);
- Detector Gaps Agent(DGA)

1. *Interface Agent (IA)*

It is an agent who acts as the interface between the learner and other agents through Manager Agent. The interface agent uses two means of communication the HTTP protocol for communication with the learner (the browser) and the language KQML for communication with other agents. It receives the request of the learner as an HTTP request; it formulates a query and sends KQML to the Manager Agent. It dissects the query to retrieve the identifier of the learning and demand from Profile Manager Agent (PMA) level, of concept(s) requested to the learner in question. IA can also receive the request for registration of a new learner or the connection request from a learner already registered (HTTP) and sends it to the PMA through the MA. It also sends the results of all assessments (Quizzes, test, and exercise) to change the profile of the learner.

2. *Manager Agent (MA)*

This agent controls all the operations performed by the system and assigns tasks to agents according to their roles they were assigned to. The agent manager, once receives a request from the Interface Agent, determines its nature in order to select agents that can contribute to fulfill this request. The requests exchanged between the IA and MA are listed and are easily identified by an id number. MA acts according to the type of complaint: course request, evaluation request, login, registration, profile editing ... etc.

3. *Contents Builder Agent (CBA)*

It receives from MA a request formulated by the learner and the level(s) concept(s) request(s). It queries the ontology of the objectives to determine the type of goal made (General objective, specific or operational) and reformulates the query so that it includes, in addition to the concepts, the learner profile and type of its goal, and sends it to the filter agent. The latter, searches and selects Hypermedia Units (one or more HULs) that match the query (target and learner profile) after the filtering agent's response, it applies the principle of dynamic composition of HULs to organize and produce a learning path executed by the learner, and then it sends it to the Manager Agent.

4. *Tests Builder Agent (TBA)*

It receives from MA a request containing the concept (s) to evaluate and the goal. The TBA demands from the FA to search and select HUAs (assessments) that match the specified criteria. After the response of the FA, TBA applies the principle of dynamic composition of Hypermedia Units to have a proper evaluation.

5. *Filter Agent (FA)*

The role of the Filter Agent is a search of HU based on criteria specified by the CBA or TBA, and then he responds by sending the addresses of Hypermedia Units received. When the FA receives the search request containing the HU(s) concept(s) it seeks the HU container(s) concept(s) and then filters among all these HU which meet those levels cognitive learner, while resting the learner profile. Another filter is applied to the content HUs, to filter HU(s) adequate(s) in physical type of media preferred by the learner.

6. *Profile Manager Agent (PMA)*

The role of the Profile Manager Agent (PMA) is to create, initialize, store and process the learner profile following a request from the agent interface and may also add a new learner and initialize its level low for all concepts. It will also change the level of the learner on a concept after evaluating the response of the learner on the tests and sends it to new level by the agent interface. Moreover, PMA consults, on request from the MA, the level of a learner in one or more concepts to help the CBA and TBA to accomplish their tasks.

7. *Detector Gap Agent (DGA)*

This agent uses similarity functions to assess the proximity of two productions (as expected and that of the learner). The result of the evaluation will be presented in a report to be used by the agent to generate a special remedial course.

5. The Artificial Neural Network Approach for the Generation of Remedial Course

The multilayer perceptron (MLP) is an artificial neural network-oriented organized in layers or information travels in one direction, from input layer to output layer. The input layer is still a virtual layer associated with the input of the system. The output layer corresponds to the outputs of the system. In a general case, a multilayer perceptron can have an arbitrary number of layers and also a number of neurons (or entries) in any layer. Neurons are connected together by weighted connections. These are the weights of these connections that govern the operation of the network and program an application of the input space to output space using a nonlinear transformation [15, 16]. As shown in Fig.8.

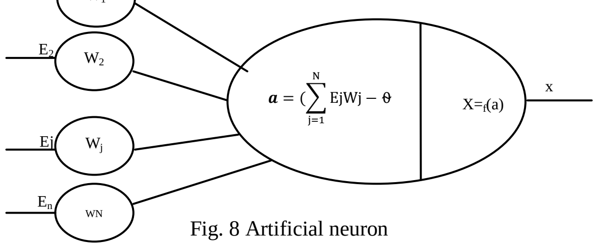

Fig. 8 Artificial neuron

The creation of a multilayer perceptron to solve a given problem requires the inference of the best possible application as defined by a set of training data which consist of pairs of input vectors (IV) and desired outputs (OV).

This inference can be made, among others, by the algorithm called back propagation. MLP models have special properties such as the ability to adapt, learn or classify data [16]. They are able to discover hidden relationships between input and output ones.

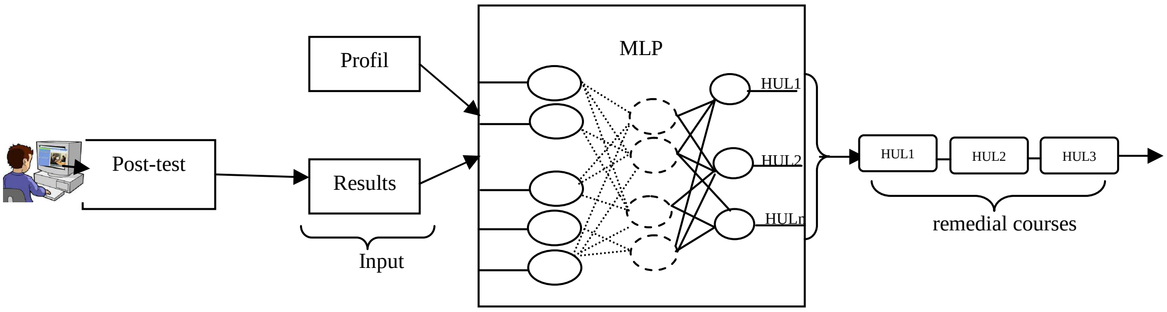

Fig. 9 The neural networks architecture adopted

The problem of the generation of adaptive remedial courses based on the profiles and behaviors of learners can be considered as a classification problem, since the purpose of this process is to find all the Hypermedia Units of learning (HUL) from the appropriate learner profile and the report of his post-tests. The course is a remedial course and that meets specific objectives, concepts unsuccessful by a learner. This path is generated according to the result obtained by the learner at the end of his training. If the student could not succeed in training, a course of remediation will be issued to confirm its achievements.

At the end of each learning process the system provides post-test learners to validate their experience and update their profiles. Then test results are sent to the Agent Detector Gap (DGA) which examines the responses of students with those of the expert in the field. This, results in a detailed report containing information on concepts mastered and those not under control.

In this paper, a multi-layer Perceptron (MLP) with one hidden layer is built to handle the task of selecting Hypermedia Units of learning (HULs) to make a decision on the understanding of the learner.

The inputs of this MLP is the learner profile and post-test report generated by the agent detector gap (AGP), the report provides valuable information to the MLP architecture to choose with great care the appropriate HULs as shown in the figure 9. Be assigned the value 0 for a concept not mastered a concept, 0.5 for medium and 1 to a concept completely mastered. The choice of Hypermedia Units that come into play for the creation of remedial courses is based on a number of rules that are a few quotes:

R1: An Hypermedia Unit of learning (HUL) is selected if its profile matches that of the learner.
R2: the HUL is selected if the level of learning in this concept is average.
R3: the HUL is selected if the level of learning in this concept is low.
R4: the prerequisite concepts are selected if the level of learning in this concept is low.
...Etc.

6. Conclusions

In this paper we have presented an intelligent architecture, oriented goals, to create individualized learning paths, based on ontologies, multi-agent systems and neural networks. This model allows students, teachers and instructional designers to work with software agents, and to automatically build customized courses which are effectively guided by educational goals. It allows the learner to follow his training at their own pace and preferences, either individually or in collaboration with others (students or tutors). Thus, the proposed model provides learners with training respecting their preferences, meeting their expectations, and creating quality custom courses for relevant educational use.

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