Ontology based User Modeling for Personalization of Grid Learning Services

Liana Razmerita[1], Guy Gouardères[2]

IRIT, Université Paul Sabatier, France
[1] *razmerit@irit.fr*

[2]Département d'Informatique, IUT de Bayonne - Université de Pau, France
Guy.Gouarderes@iutbay.univ-pau.fr

Abstract: Several challenges need to be met by a new generation of learning services. On the one hand they need to fit into a ubiquitous and serendipitous learning vision, to adapt to many different types of users with different backgrounds and needs. On the other hand they need to integrate modern pedagogical approaches of learning. These services will probably rely on the cooperation of different distributed, autonomous, goal-oriented entities and they can be grid or web-oriented. In this paper we show how core technologies can contribute to the development of a next generation of learning services. In particular, we focus our attention on personalized services delivery for learning by employing an ontological perspective and user modeling techniques. The paper presents some preliminary results obtained within Elegi FP6 project.

Key words: personalization, grid learning, user modeling, heterogeneous users, ontology, ubiquitous computing.

1. Introduction

There is a need for new empowered tools to enhance the web-enabled learning spaces. Despite years of research in the area, e-learning is still facing provocative challenges related to how better to support learning processes on the web. On the one hand the continuous development of new technologies (Grid Computing, Semantic Web, etc) has opened new perspectives for more advanced, enhanced learning services. On the other hand new paradigms of learning need to be integrated in the design of these new learning services. A new vision of learning requires a fundamental shift from current content-oriented e-learning solutions towards a more user-centered, interactive and collaborative model of learning. The new paradigms of learning approach learning processes more then a simple absorption of knowledge and data; the learner is no longer a simple passive receiver of knowledge, he is stimulated to play an important role in constructing his knowledge; learning processes are taking place through complex interactions (e.g. learning by doing, educational games, simulation environments, problem based learning, learning by discussing, etc) Such complex interactions could take place on the web supported by new technologies such as Semantic Web and Grid Computing.

There is a multitude of knowledge and information sources available on the web that can constitute "learning objects". In a Semantic Grid vision these learning objects can be pooled by various computing nodes. Grid computing will enable transparent location access to simulation environments, real-world input, 3D systems, digital libraries, etc. Metadata associated with the learning objects combined with characteristics of the users will play a very important place in selecting and retrieving the right piece of knowledge or learning object. Thus a rich collection of learning services can be offered to the users. Agents can carry out sophisticated tasks for the users: they can diagnose the user, they can propose different types of learning objects with different characteristics or they can tutor the students in acquiring new concepts.

One of the long-term objectives of Elegi FP6 project is to study how the Semantic Grid will enable to build a seamless intelligence for services on the web. We believe that the seamless intelligence of learning services will ally user-centered concepts such as: P2P, affective computing, serendipity with other socio-centered concepts such as: collective intelligence, ubiquitous computing and amorphous computing.

The paper shows how Semantic Grid learning services will support a user-centered, personalized, contextualized and experiential based approach for ubiquitous learning. In order to allow personalized learning processes we need to study and define methodologies for representing knowledge, through adequate knowledge structures, such as ontologies, both the domain (the learning context) and the learner. In this paper we will focus on the role of ontologies for a next generation of intelligent services, and more specifically, about their role for Semantic Grid Services.

The paper is structured in five sections. The second section presents the rationale of semantic web vision allied with grid computing technology. In the third section we describe core technologies enabling the development of a new generation of grid learning services. The fourth section presents the integration of these core technologies within a learning grid scenario and the ASIMIL case study. We end by drawing some conclusions and planning future work.

2. Ontologies and Semantic Web technology meets Grid Computing

In the last few years ontologies have become a silver bullet in the area of knowledge representation and knowledge modeling. Ontology describes a formal, shared conceptualization of a particular domain of interest. The ontology research has developed due to an increased need of more powerful knowledge representation mechanisms for knowledge sharing and reuse. The research on ontology also promises the development of the World Wide Web towards Semantic Web (SW).

The notion of Semantic Web is a term coined by Tim Berner Lee (1999). In his vision, the semantic web will have a five layer structure:

- XML layer is viewed as a syntax layer.
- RDF/RDFS layer or metadata layer.
- The ontology languages layer enables to specify the meaning of the data.
- The logic layer adds intelligent reasoning mechanisms.
- The proof layer enables to “proof” the results of the automated services.

Nowadays there is a lot of research in the domain of Semantic Web. The research on Semantic Web is mainly concerned with the third layer, the ontology language layer. Web oriented languages such as: XML, RDF/RDFs and more recently OWL, recommended as Web standards by W3C, represent the basis for the ontology language layer. Semantic Web aims to build a WWW architecture that enhances the content with formal semantics. The main role of semantic is to improve the search mechanisms but there is more potential associated with the use of semantic enriched information on the web. Data, information and knowledge enriched with formal semantics enable the creation of advanced applications that automatically process information. Metadata and agreed conceptualizations will enable different agents to process and reason based on the Web content in order to provide different intelligent services.

In the last few years, many researchers have approached the Semantic Web research challenges, namely “bringing the web to its full potential”, and many articles have recently appeared on this subject (Decker et al., 2001; Bozsak et al., 2002; Henler, 2001; Staab, 2002; De Roure, 2001). The new generation of the Web, also named as Wisdom Web appears as a promising technology for implementing new added value services (e-learning, e-business, etc.). [1]

The SW vision was recently adopted by the educational scholars (amongst others: Koper, 2004; Clark et al., 2004; Stutt and Mota, 2004). Semantic representations may solve some basic problems in Education. Semantic enriched representations or annotated resources on the web could become learning objects that could be more easily retrieved, processed and manipulated. Annotated educational resources combined with new means of reasoning open the perspective of a new range of associated learning services.

One of the most important current evolutions in networking is represented by Grid Computing (GC). The GC architecture is a computational network infrastructure working based on a cooperative use of the different computing resources connected on Internet based on a peer to peer communication protocol. The GC concept also identifies a crucial roadmap for fundamental research in computing around the notion of Semantic Grid services.

[1] Foster, I., Frey, J., Graham, S., Tuecke, S., From Open Grid Services Infrastructure to Web Services Resource Framework: Refactoring and Evolution.

3. Core technologies for a next generation of services

In the following we will summarize and explain why the following core technologies will be the basis for a next generation of services on the web.

3.1 Peer-to-Peer networks

The scope and reach of peer to peer networks has increased significantly since the success of user friendly file sharing networks such as: Kazaa, Gnutella and Napster. The two main models of file sharing applications can be classified in two categories: centralized applications (Napster) versus decentralized applications (Gnutella). These popular applications brought a new perspective to the use of peer-to-peer (P2P) and file sharing systems. Moreover, they have been adopted as a model of communication for the Grid Computing infrastructure. In a P2P communication mode the users decide whether resources they want to share resources or not and which ones.

3.2 User modeling

User modeling is a multidisciplinary and broad area of research. Numerous researchers have reported on: human-agent interaction, how to construct adaptive systems, how to tailor and filter information, how to personalize help and dialogue systems, how to personalize interaction in e-commerce, e-learning, knowledge management systems (Brusilovsky, 2001; Kobsa et al., 2000; Stephanidis, 2001; Kay, 2001; Andre et al., 2000; Razmerita, 2004)

In the last few years, among many objectives related to user modeling research, personalization has emerged as an important strand. In general, the goal of personalization is to improve the efficiency of interaction with the users, to simplify the interaction and to make complex systems more usable. Important application areas of personalization include: customer relationship management, educational software, web search and retrieval. In the last few years, problems of personalized interaction in mobile, ubiquitous and context-aware computing, aspects of personalization in the user interaction with embodied, autonomous agents, personalization of future TV have emerged. The authors of the paper argue that personalization and contextualization need to be better supported by a next generation of seamless intelligent services on the web.

3.3 Ontologies and semantic enriched representations

Ontology consists of a set of concepts and relationships that describe a domain of interest. Defining a set of terms for structuring the data and the relationships between the different terms means to define ontology. In more sophisticated cases suitable axioms are added in order to express other relationships between concepts and to constrain their interpretation. "The role of an ontology, is considered as a set of logical axioms designed to account for the intended meaning of a vocabulary" (Guarino, 1998)

Ontologies offer representation and reasoning possibilities and can be equipped with formal semantics. Ontologies were initially developed for knowledge sharing and reuse. They now apply to a much broader context of research. Information overload problem and the need to better filter and process automatically the web resources are just a few arguments for the increasing interest in ontology research. In the context of web, the use of ontologies and metadata enables better search mechanisms and the opportunity to build a new generation of web-enabled services. The question of how to better meet the user needs and help the users to access and use the vast amount of resources available on the web efficiently is a challenging idea for a new generation of advanced services on the web combining ontology and user modeling.

3.4 Multi-agent systems

Software agents possess attractive features including autonomy, proactiveness, intelligence (reasoning capability), social ability (interaction with the environment, user and other agents) and mentalist characterization (beliefs, desires, motivations, etc) that can be used to build advanced distributed systems. The flexibility and high-level nature of these interactions distinguishes multi-agent systems from other forms of software and which provides the underlying power of the paradigm. (Jennings and Wooldrige, 2002)

Multi-agent systems have the traditional advantage of distributed and concurrent problem solving and have the additional advantage of sophisticated patterns of interactions. In multi-agents systems different types of specialized agents are cooperating in order to achieve different goals. Agent-based systems are often used in advanced learning systems. Among the recent work in the area: (Brna et al. 2001, Roda et al. 2003, Goarderes 2000, Woolf et al., 2002)

3.5 Grid Computing

Since its inception in the mid 90's, Grid Computing has been aimed at supporting dynamic, late-binding, and distributed applications, thus creating a better-suited, more powerful platform for multi-agent systems. However early work in computational grids differs from agent-based systems in scope, features, capabilities and target application domains. The goal for Grid Computing is closer to traditional distributed systems. Semantic matchmaking traditionally has been an agent oriented characteristic, it has also been incorporated recently by GC research. As it has already been presented in section 2, a lot of recent work is nowadays oriented towards Semantic Grid research. (De Roure, 2001)

4. Learning Grid scenario: e-Qualification services in ASIMIL

In the following subsections we present a scenario for using an application from aerospace domain called ASIMIL (A Network Distributed Simulator Training System). Grid computing has as an ultimate objective to increase business efficiency and it is an adapted infrastructure for advanced applications in aeronautics and other application domains. ASIMIL has to be adapted for the use in the Semantic Grid environment. However the question of how to realize the vision of Semantic Grid for this application is still an open question. We advance the idea of using ontologies for ASIMIL application scenarios; it is a first step for making it fit for the Semantic Grid vision. The use of ontologies for modeling the user and the application domain would facilitate the communication of the various agents that are populating ASIML. Many learning processes supported by ASIMIL relate to a dynamic learner profile and associated user modeling processes. Therefore in Section 4.2, we present an ontology-based user modeling associated with the learner profile.

4.1 Evolution of the intelligent performance systems in aeronautics

In the last few years aerospace organisations have been under extreme pressure to remain competitive. For example, in the airline sector reduction in aircraft maintenance time results directly in lower operating costs and increased revenues. In Air Traffic Control, there is a need to extract higher capacity out of the limited air space (especially in Europe) and airports are confronted with increasing their throughput of aircraft and passengers.
In this context, intelligent decision making has a particularly large potential for application in order to improve processes efficiency and raising economical benefits. In particular, within the aerospace domain, one of the main challenges is the lack of a widely accepted methodology for selecting problem solving technologies. Grid Services rises as a possible solution to the above challenge, by making available a low cost and more standard embedded intelligent technology, for classifying problems, selecting solving tools and promoting inter linking.

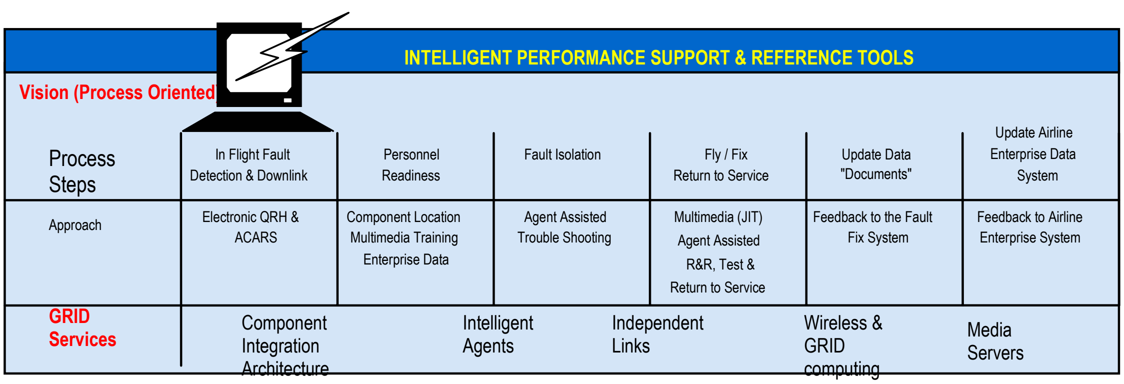

Figure 1. *Oriented process vision for intelligent performance support (N. Suri & al.)*[2]

[2] NOMADS: Mobility Support for the CoABS Grid, Niranjan Suri, Jeffrey M. Bradshaw, Maggie R. Breedy, Marco M. Carvalho, Thomas B. Cowin, Paul T. Groth, Institute for Human and Machine Cognition, UWF, Pensacola

4.2 Ontology-based user modeling

The first ideas of using ontologies for learner modeling have been reported by Chen & Mizoguchi (1999). Kay (2001) also argues for the use of ontologies for reusable and "scrutable" student models. More recently the idea of using sharable data structures containing user's features and preferences are proposed in order to enable personalized interactions with different devices to the user's benefit. For this purpose, a user modeling mark-up language for ubiquitous computing built on XML technology has been proposed as a platform for communication by Heckmann & Krueger (2003).

Razmerita (2003b) proposes an ontology based user modeling framework and shows how the user ontology can be applied in the context of a Knowledge Management System. The user model proposed by Razmerita (2003a) is defined as a generic user ontology describing the different characteristics of a user and the relationships between the different concepts. A partial view of the user ontology using a graph based representation using KAON, OI-Modeler is represented in Figure 2. KAON is a tool suite for ontology management and for the development of ontology based applications. (Maedche et al., 2002)

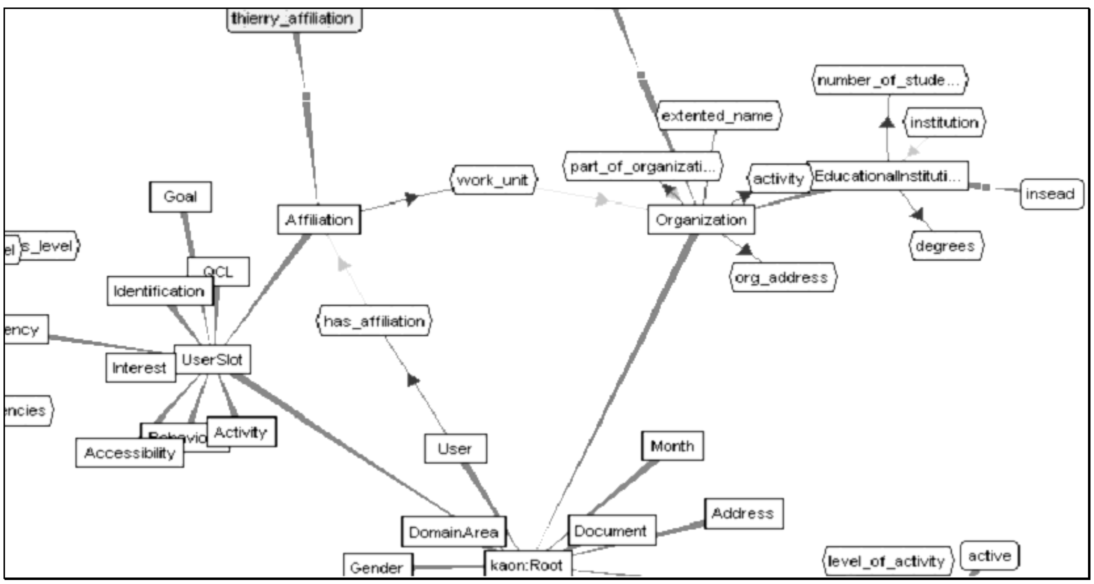

Figure 2 *A partial graph-based view of the user ontology*

The definition of the user ontology captures rich metadata about the employee's profiles comprising different characteristics such as: name, email, address, competencies, interests, qualifications, preferences, but also a behavioral profile specific to the user interaction with a Knowledge Management System. The proposed user model is extending the Information Management System Learner Information Package specification (IMS LIP, 2001). IMS LIP is structured in eleven groupings in including: Identification, Goal, QCL (Qualifications, Certifications and Licenses), Accessibility, Activity, Competence, Interest, Affiliation, Security Key and Relationship. These groupings are implemented as abstract concepts in the user ontology. The concept "Identification" contains attributes and other sub concepts that help to identify an individual (e.g. name, address, email) within the system. **"**Affiliation" includes information on the descriptions of the organizations associated with the user/learner. "QCL" contains concepts related to the different qualifications, certifications and licenses the user has. "Competence" contains skills associated with formal or informal training or work history. "Activity" includes activities related to the education/training work of the user. **"**Accessibility" contains concepts related to: user preferences, language information, disabilities etc. The concept "Interest" contains information on hobbies and other recreational activities. The concept "Goal" contains learner's/user's goals. The user ontology contains a set of concepts, a set of taxonomic relations (User, Learner) and a set of non-taxonomic relations ("User works_on Project", "User has_affiliation Affiliation"). The non-taxonomic relations are usually connecting users with domain specific concepts. These relationships are very useful for reasoning and inferring new knowledge. For example matchmaking agents can retrieve the "like minded" users, interested in a certain domain and map them into a community of practice. For the ASIMIL scenario only a part of the proposed user ontology is necessary. In a second phase the user ontology has to be mapped to the domain ontology. Ontology based user modeling requires a referential structure which can be static (e.g subconcept Name of the IMS LIP abstract concept Identifiction) and an adaptive part which in a learning context need to evolve according to the user's progress in learning, according to his goal, domains of interest which need to be acquired and updated (concepts like Interests, Goal). The dynamic part of the user ontology could be updated using machine learning techniques (Maedche, 2002) or other ontology-based reasoning mechanisms (Razmerita, 2003a). For example if the user works on Elegi project, and Elegi project is described to be related to Grid Computing, an ontology-based system can infer using reasoning mechanisms, such as F-logic, that the user might be interested in Grid Computing. Thus without asking the users to update their characteristics an ontology based user modeling system, such as OntobUmf (Razmerita, 2003a), would be able to update dynamicaly the user's data. Recent research work include a considerable effort towards automatic ontology evolution based on usage data (Stojanovic and Motic, 2003; Park et al. 2003).

From a more learning centered scenario, based on the learning goal of the user and the metadata of the learning objects the pedagogical agent can propose various learning object that fit the learner's objective and expertise. For example if the learner wants to train himself to pilot an airplane (described as the learner's goal in the user ontology), he will be able to access different flight simulations amongst which also ASIMIL.

4.3 ASIMIL: A Network Distributed SimulatorTraining System

The experimental framework for the ASIMIL training system is simulation-based Intelligent A peer-to-peer-review process which is performed by autonomous agents (as Knowledge, Ergonomic, Psychologic). Each agent scan separately a common stream of messages coming from other actors (human, intelligent agents, physical disposals). They perform coalitions to supply a given community of users (instructors, learners, moderators,…) with diagnoses, advices and helps among actors in the community.
This multi-agent system architecture is called ASITS (Actor Specification for Intelligent Tutoring Systems) (Gouardères, 2000) and is directly adapted from ACTORS (Frasson & al., 1996) by including a cognitive architecture based on ACT-R/PM that specifies the role of the cognitive resources in the high level cognitive tasks and adopt proposals exchanged at the time of a conversation.

Within the ASITS agent's framework, ACT is for "Adaptive Control of Thought" preferred to "Atomic Components of Thought". (Anderson 1996), R stands for "rationale accepted as Revision or Reviewing" and PM stands for "perceptual and motor", monitoring of task (Byrnes, 2001)

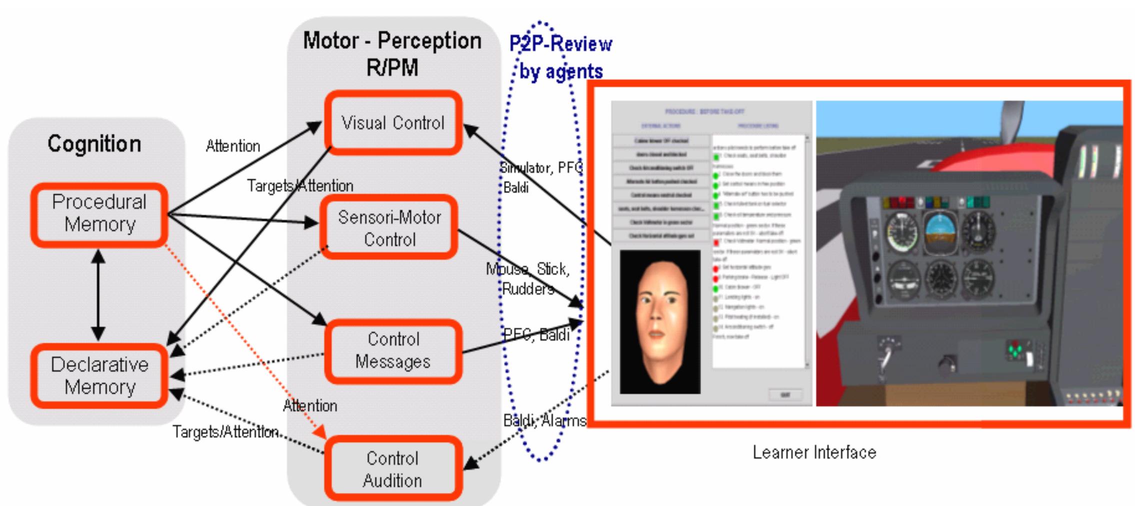

Figure 3. *Cognitive control of dialogue's modalities by ACT-R/PM model in ASIMIL*[3]

[3] ACT-R/PM architecture is presented on the left part of figure. ASIMIL interface – on the right part (System of procedures follow-up on the left, flight simulator on the right and an animated agent (Baldi))

In ASIMIL, we need to control several methods of parallel dialogue and exchanges (messages - texts, word -, orders - mouse, stick, caps -, instructions, alarms - visual, sound -...).(see Figure 3). The knowledge that must be provided to ASITS' agents to complete a model of a person in an environment is essentially of two types: declarative and procedural.
Declarative knowledge is represented in symbolic structures known as *chunks.* Procedural knowledge sometimes referred to as "know-how" knowledge, is stored in symbolic structures known as *production rules,* and are mostly used to find overlays between produced chu*nks*.
We have used the ACT-R/PM as inference engine for the global ASITS architecture (module of cognition connected to perception-motor module) and a strong psychology theory (Rasmussen, 1986, Norman, 1991), on how interaction occurs. Furthermore, ASITS architecture (Agent Team) allows producing concurrent diagnostics in real-time, according to the following high-level communication loop:

- Perception: PM, The agent perceives its environment continuously to sense any new situations.
- Reason for goal selection: R, The agent infers the next goal, based on its goal model, knowledge, and the perception of its environment. (R', same for an action selection).
- Act: The selected actions are executed.
- When a coalition is gained the characteristics will be sum up in a vector which is broadcasted to others agents and coalitions for searching P2P cooperation and bests overlays fitting in what we call a Focused Crawling between potential chunks
- The final matchmaking process results from the moderation between coalitions proposals by subjective clustering. (Iterative re-qualification of the influence of each coalition in a selected chunk).
- When one of the actors carries out an assessment, he/it can recover the chunk (as an Abstract + Acknowledgement + notification) to update his knowledge and an alarm is broadcasted to launch the P2P review again.

4.4 ASIMIL: A Peer-to-Peer Networking of agents to map the user in his community

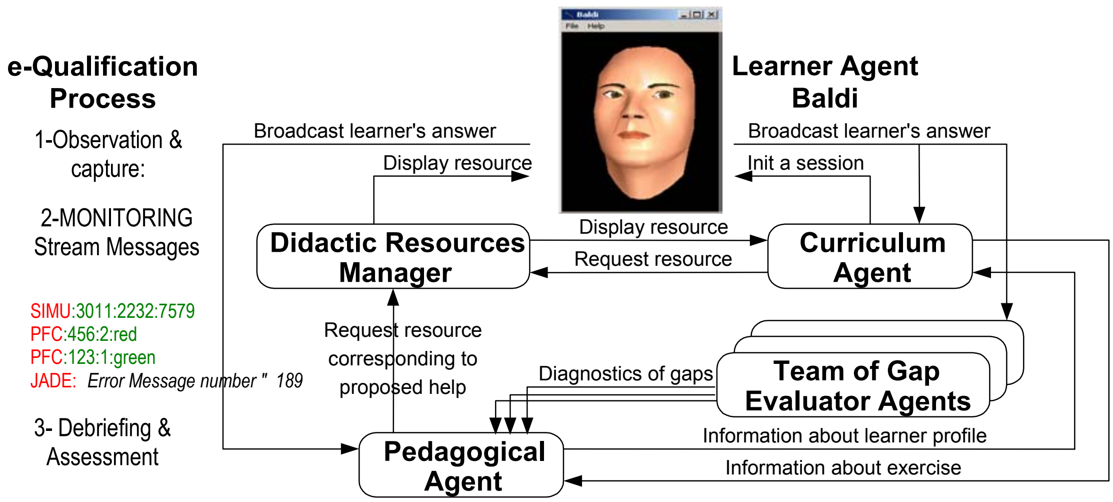

Figure 4. *e-Qualification process in ASIMIL*

A dedicated P2P-Agents architecture for perception and qualification of erratic user's behaviours has been constructed which consists of a cognitive monitoring based on intelligent agents.
The various agents of this architecture are:

- Interface agent ensures the communication between the MAS and the other components of the system (simulator, virtual reality, procedures).
- Curriculum agent traces the evolution of learner in interaction with the system and builds history.
- team of agents-evaluators of errors realises diagnoses of learner's errors according to three axes: knowledge, ergonomy or psychology. Each of them is an expert in a particular domain of knowledge.
- Learner's profile agent provides an image (profile) of the state of the learner (knowledge, reasoning and possibly misconceptions -ergonomy, psychologie), which is dynamically updated as the learner progresses through tutoring sessions.
- Pedagogical agent carries out the evaluation and helps learning.

Unfortunately, this current version of ASIMIL is multi client-server based: simulation, agent, CBT servers act as autonomous systems but with supplier-to-customer services. Another inadequate situation stems from the pedagogical agent that combines the role of user's advisor with that of mediator to a) co-ordinate the activities of other agents and b) deliberate on the conflicts that appear (acting as judge and jury rules out the "peeriness" from the community).

4.4 ASIMIL: Peer-to-Peer Networking as (P2P) to restore the "peeriness" between agents

The objectives for the agent team have changed. New assigned goals aim to achieve a progressive reconstruction of the collective reasoning of learning within a group of users by Focused Crawling. We use Local Bayesian Networks to validate the successive states of the user knowledge within his community and to guide the extraction of the information from the stream of messages. These networks are built from the user's profiles of and the issuess of agents' coalitions.
The framework to shift the current view from a Peer-to-Peer networking of to a (P2P) one proceeds in for steps:

Step1: Focused Crawling Process is a mapping of people who are communicating in P2P dialogue by message selection. P2P-Networking stream messages are in broadcast mode and agents have to collaborate (Coalitions, Accointancies, …) to extract the correct message, which can be pertinent for each one to set up an emergent partnership to target the assigned goals, (for example, in the sample list of messages below) :

SIMU:3011:2232:7579
PFC:456:2:red
PFC:123:1:green
JADE: *Error Message number " 189……*

Step2: The Subjective Clustering **"Overlay"** allows an user to make the most from a mirror effect of his state in relation to others. A "overlay" vector $\vec{E}$ evaluate the acceptability of an "overlay" between a candidate user profile and an assessed one as referential by minimizing the deviation (i.e., the "errors") from the point of view of three characteristics (Knowledge, ergonomy, psycho-physiology) : the « Overlay » vector is based on coef xi = (error i, gravity i)

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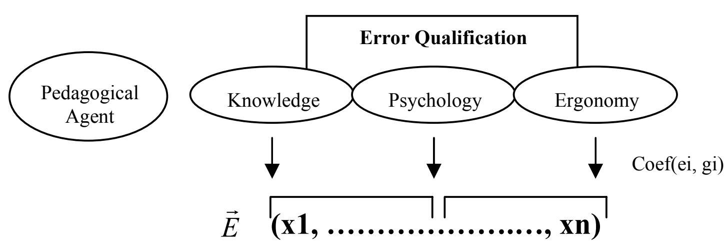

Figure 5. *Subjective Clustering is a tentative mapping of the user in a community*

Step3: Creation of the associated Grid Service by Peer-To-Peer Review: "Selects Error-Agent Output» as a reusable Chunk!

1- Between one Error-Agent Output over the current list
2- The decision of selecting a new Output from another agent is the Peer-to-peer Review between agents and corresponds to the mapping process: (a) deepen a Output; (b) shallow scan; (c) review previous output; (d) select a new output.

The best overlay result is kept and a matchmaking process is done between different hypothesis (constructivist) and the current profile of the learner (behaviourist) which is the mirror effect of one on another. The chunk is validated.

Step 4: An alarm indicating that someone has entered the (new) community (Gap bridged successfully between two P2P community).

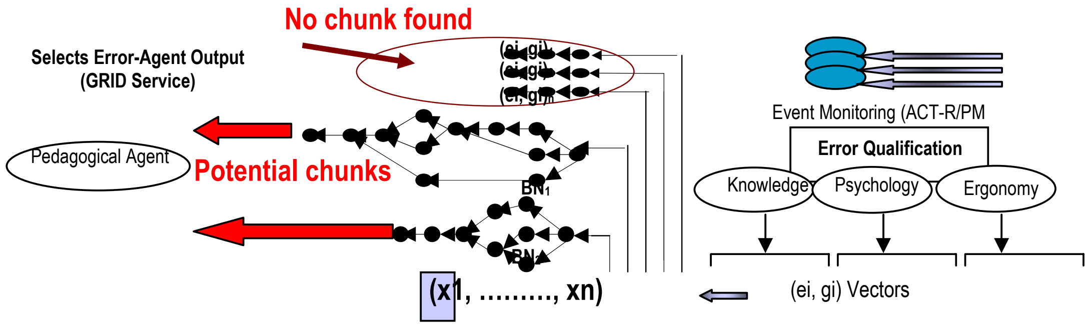

Figure 6. *Matchmaking process by peer-to-peer review between agents*

5. Conclusion

Are we going to be able to build more flexible and adaptive e-learning systems using Semantic Grid technology or is Semantic Grid Learning going to overcome limitations of the current e-learning systems? We don't have the answer yet but we assume that Grid Computing can support a next generation of learning services. The paper has presented a set of core technologies that are ready to be applied for the new Semantic Grid vision. Personalization and contextualization of services are becoming inescapable features for the future applications and seamless intelligence of the web. But personalization and contextualization requires access to the user's data or learning about the users through associated user modeling processes. Ontologies are the most suitable representation mechanism for achieving the Semantic Web vision and the Semantic Grid vision. Ontology-based user modeling requires a referential structure which can be static but also an adaptive part which need to evolve according to the user's progress in learning according to his goals, domains of interest which need to be acquired and updated.

From this utility and conviviality perspective a next generation of learning services will enable us to adapt and to match the needs and the preferences of users based on a user model which is stored and updated dynamically. In order to integrate these two functions and to better support their users partial user models need to be constructed and maintain. Personalization and contextualization has a utility function and a conviviality function. From the utility perspective, 1) personalization reduces the information overflow by providing users with the most relevant information. 2) contextualization helps fitting the functionality of the system to the user's context and needs. From the conviviality perspective, personalization helps to bridge the gap between the "designer's view of the system" and the end-user's view of the system and to take into account the user's preferences.

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