An XML Multi-Agent System for e-Learning and Skill Management

Alfredo Garro[1] and Luigi Palopoli[2]

[1] D.E.I.S. - Università della Calabria, Via P. Bucci,
87036 Rende (CS), Italy
garro@si.deis.unical.it
[2] D.I.M.E.T. - Università "Mediterranea" di Reggio Calabria, Località Feo di Vito
89060 Reggio Calabria, Italy
palopoli@ing.unirc.it

Abstract. E-learning is nowadays recognized as one of the key components of Enterprise Knowledge Management platforms. Given a project specification, the platform should be able to suggest a project team, to measure human resources competence gaps and to contribute to reduce them by creating personalized learning paths. In this paper we propose an XML based Multi-Agent System to perform the following tasks: *(i)* supporting Chief Learning Officers in defining roles, associated competencies and knowledge level required; *(ii)* managing *skill map* of the organization; *(iii)* measuring human resources competence gaps; *(iv)* supporting employees in filling their competence gaps as related to their roles; *(v)* enriching a given courseware or creating personalized learning paths according to feedbacks user provides in order to optimize the acquisition of needed competencies; *(vi)* assisting Chief Learning Officers in choosing the most appropriate employee for a given role.

1 Introduction

Among the themes that are currently central in the market of the ICT (Information and Communication Tecnology) a special place is occupied by e-learning. The increasing and generalized attention toward e-learning, especially in the sector of business training, has various causes, that are briefly addressed below. Whereas the advantages of e-learning has been for years characterized simply in terms of gained cost effectiveness (both in terms of time and space), it is nowadays widely recognized that its potentialities go far beyond, involving issues like diversification of learning paths and general business competitive advantage [6,7,9,10]. Nowadays, it is quite agreed that organizations have not much to gain in adopting e-learning platforms that only provide educational content. An advantageous e-learning platform should have instead the capability to help enriching, sharing and circulating organization knowledge, thus being a tool able to make the organization dynamic and flexible. Because of the dyna-

mism of the market, often organizations cannot program in the medium-long term, but need to work in a project-shaped, short-to-medium term perspective. When an organization is to carry out a project, new competencies are typically to be acquired, which are frequently expensive and hard to find in the external market (the *skill shortage* problem). Therefore it is often the case that such competencies must be found (or constructed) inside. An appropriate and properly used e-learning platform thus becomes an important component of the Enterprise Knowledge Management [4,8]. Given a project specification, the platform should be able to suggest a project team, to measure human resources competence gaps and to contribute to reduce them by creating personalized learning paths. Moreover, the platform should be able to dynamically readapt, learning paths according to feedbacks users provide in order to optimize the acquisition of needed competencies. In this scenario, it appears meaningful to look at educational contents as organized in relatively small independent units (Learning Objects), which can be combined in order to create personalized learning paths. In order to achieve an appropriate management of a Learning Object database, it is necessary to describe its content in an efficient and effective way. In other words, we need a meta-knowledge that allows us to classify learning objects (documents, slides, simulations, role plays, questionnaires, pre-recorded lessons, classroom lessons, …) and their relationships with respect to their objective, topic, used media, etc... (i.e. Learning Object Metadata). Furthermore, in order to allow exchanging, reusing and sharing of learning objects, we have to express the meta-knowledge using standard formats and protocols. And, in fact, standardization of learning objects description is one important goal for the scientific community that operates in the field of e-learning The authoritative organization IMS[1] proposes to describe the Learning Objects through an XML document validated with respect to an *XML schema* established by the standard [2]. This standard has been defined and most of the commercial e-learning platforms support it. But the fundamental problem of managing Learning Objects is still to be solved. In particular, within the Skill Management context, the following main tasks are to be considered:

- Individuating the *student* learning objectives and evaluating his competence gaps.
- Building, starting from a database of Learning Objects, the courseware able to fill such competence gaps.
- Controlling the *student* improvements and (re)adapting and integrating the courseware content and presentation structure.
- Creating a bridge between single user learning objectives and general organization learning objectives.
- Managing the *skill map*[2] of the organization and updating it according to the *student* learning improvements.

All those tasks are currently carried out “manually”. The idea that we propose here is trying to automatize, as far as possible, those activities by designing suitable Multi-

[1] Instructional Management System, http://www.imsproject.org

[2] A skill map stores, for each employee, information about his/her role in the organization, the competencies required for that role and the current level of employee competencies

Agent environments. Agents technologies seem to be well suited to carry out the main activities listed above. In fact, those activities require communications between distributed components, sensing and monitoring of the environment and autonomous operations; agents have the ability to reason, they can easily perform sequences of complex operations based on messages they receive, their own internal beliefs and their overall goals and objectives. Furthermore an e-learning agents platform is expected to be proactive, interactive, adaptive and cognitive.

In this paper we propose an XML based Multi-Agent System to perform the following tasks: *(i)* supporting Chief Learning Officers in defining roles, associated competencies and knowledge level required; *(ii)* managing *skill map* of the organization; *(iii)* measuring human resources competence gaps; *(iv)* supporting employees in filling their competence gaps as related to their roles; *(v)* enriching a given courseware or creating personalized learning paths according to feedbacks user provides in order to optimize the acquisition of needed competencies; *(vi)* assisting Chief Learning Officers in choosing the most appropriate employee for a given role.

We call our system *Multi-Agent System for E-Learning e skill management (MASEL)*. The system we propose includes seven kinds of agents:

1. *CLO Assistant Agent*, that supports Chief Learning Officers in defining a learning strategy in terms of roles and competencies required for the organization;
2. *Skill Manager Agent*, that stores, for each employee, information about his/her role in the organization, the competencies required for that role and the current level of employee competencies (*Skill Map*);
3. *Student Assistant Agent*, that supports student in improving his/her competencies;
4. *Learning Paths Agent*, that deals with creation of learning paths;
5. *Content Agent*, that is specialized in managing a Learning Object Database;
6. *CCO Assistant Agent*, that supports Chief Content Officer in managing a Learning Object Database;
7. *User Profile Agent*, that stores all the needed information about the users (e.g., login information, learning activities information and so on).

Such agents will have to be FIPA[3] compliant [1], and able to operate, at least, in e-learning contexts based on the LOM (Learning Object Metadata) paradigm according to the IMS standards [2]. It should be clear, from the description provided above, that information exchange plays a central role in MASEL. Actually, the efficient management of information exchange has become a challenging issue in most areas of computer science research, particularly for Web-based information systems. In this area, the most promising solution to this problem was the definition of XML, a language for representing and exchanging data over the Internet. XML embodies both representation capabilities, typical of HTML, and data management features, typical of DBMS's; it is presently considered as a standard for the Web. XML capabilities make it particularly suited to be exploited in the agent research; as a matter of fact, agents using XML for both representing and handling their own ontology have been proposed, especially in the e-commerce area [5,16]. MASEL is an attempt to extend this trend to *E-*

[3] Foundation for Intelligent Physical Agents, http://www.fipa.org

Learning and Skill Management agents; in particular, in our multi-agent system, XML is exploited both for representing and handling agents' ontology as well as for managing data exchange among them.

The rest of this paper is organized as follows: Section 2 describes the MASEL architecture by pointing out both provided services and the ontology of the MASEL Agents. An overview of MASEL behaviour is presented in Section 3. Finally, in Section 4 we draw our conclusions.

2 MASEL Architecture

As previously pointed out, MASEL consists of seven typologies of agents, namely CLO Assistant Agent (CLO), Skill Manager Agent (SMA), Student Assistant Agent (SAA), Learning Paths Agent (LPA), Content Agent (COA), CCO Assistant Agent (CCO), User Profile Agent (UPA).

2.1 The CLO Assistant Agent

Provided Services. A generic *CLO* supports a Chief Learning Officer in managing the *skill map* of an organization and defining a learning strategy in terms of roles and required competencies. *CLO* provides the following services:

- managing roles and competencies: CLO supports the user in defining roles, associated competencies and knowledge level required;
- managing employees with relative roles and competence levels;
- suggesting the most suitable employees for taking a specific role;
- defining priorities or/and temporal constrains relative to competencies that have to be acquired by employees;
- showing, for each employee, the learning activities history.

```
<!ELEMENT CLOAssistantOntology (SkillMap,LearningHistory*)>

<!-- SkillMap is defined in SMA Ontology -->
<!-- LearningHistory is defined in SAA Ontology -->
```

Fig. 1. The DTD describing the Ontology of a CLO Assistant Agent

Ontology. The ontology of a generic *CLO* consists of an XML document storing information about the *skill map SM* of the organization and, for each employee Em_i, her/his *learning history* lh_i. The ontology of a MASEL *CLO* is described by the DTD shown in Figure 1.

2.2 The Skill Manager Agent

Provided Services. A *SMA* manages the *skill map SM* of the organization. *SM* stores the information, previously inserted by a *CLO*, about roles and associated competencies. Moreover, for each employee Em_i, *SMA* manages the information about Em_i role and Em_i current competence levels. *SMA* provides the following services:

- inserting, deleting and updating organization roles and competencies;
- inserting, deleting and updating employees' roles and competencies;
- querying the *skill map*. For example: searching the most suitable employees for a specific role; evaluating an employee competence gaps.

```
<!ELEMENT SkillManagerOntology (SkillMap)>
<!ELEMENT SkillMap (Role*, Competence*, Em-
ployee*)>
<!ELEMENT Role (RequiredCompetence+)>
   <!ATTLIST Role
      Identifier ID #REQUIRED
      Name CDATA #REQUIRED
   >
<!ELEMENT RequiredCompetence (Competence)>
   <!ATTLIST RequiredCompetence
      RequiredLevel CDATA #REQUIRED
   >
<!ELEMENT Competence EMPTY>
   <!ATTLIST Competence
      Identifier ID #REQUIRED
      Name CDATA #REQUIRED
      Description CDATA #IMPLIED
   >
<!ELEMENT Employee (PersonalData, Role, Em-
ployeeCompetence*)>
   <!ATTLIST Employee
      Identifier ID #REQUIRED
   >
<!ELEMENT EmployeeCompetence (Competence)>
   <!ATTLIST EmployeeCompetence
     CurrentLevel CDATA #REQUIRED
   >
<!ELEMENT PersonalData (firstName, last-
Name, gender, birthDate, birthPlace,
nationality+, languageUnderstood*, ad-
dress+, phoneNumber+, emailAd-
dress+,note?)>
<!ELEMENT firstName (CDATA)>
<!ELEMENT LastName (CDATA)>
<!ELEMENT gender (Male|Female)>
<!ELEMENT birthDate (CDATA)>
<!ELEMENT birthPlace (CDATA)>
<!ELEMENT nationality (CDATA)>
<!ELEMENT languageUnderstood (CDATA)>
<!ELEMENT address (CDATA)>
<!ELEMENT phoneNumber (CDATA)>
<!ELEMENT e-mailAddress (CDATA)>
<!ELEMENT note (CDATA)>
```

Fig. 2. The DTD describing the Ontology of a Skill Manager Agent

Ontology. The ontology of a generic *SMA* consists of an XML document storing information about the *skill map SM* of the organization. The skill map *SM* consists of a set of roles, competencies and employees. A *role* is described by an identifier, its name and its required competencies. Each *required competence* specifies, for a particular role, the minimum level of knowledge required for the competence to fit that role. A *competence* is described by an identifier, its name and its description. Finally, an *employee* is characterized by an identifier, its personal data, its role and its competencies. In such a case *SM* stores, for each *employee competence*, the current level of employee knowledge. The ontology of a MASEL *SMA* is described by the DTD shown in Figure 2.

2.3 The Student Assistant Agent

Provided Services. A generic Student Assistant Agent SAA_i is associated with a student (employee) Em_i and assist her/him in filling her/his competence gaps related to her/his roles. SAA_i provides Em_i with the following services:

- showing the gaps between her/his current competencies and the competencies required for her/his role in the organization, possibly associated with priorities or/and temporal constrains. This task is carried out in cooperation with the Skill Manager Agent;
- evaluating a specific competence gap by *pre-assessment* tests and finding or creating courseware allowing for filling that competence gap. This task is carried out in cooperation with the Learning Paths Agent;
- enriching and modifying a courseware according to feedbacks user provides in order to optimize the acquisition of needed competencies. This task is carried out in cooperation with the Learning Paths Agent;
- managing information about current learning activities of the student.

Ontology. The ontology of a generic *SAA*, associated with a student Em_i, consists of an XML document storing information about the *profile* up_i of Em_i and the Learning Objects which are currently used by Em_i. A *user profile* up_i consists of a *learning history*, a *login information* and a set of *session log*. A *learning history* consists of a set of selected Learning Objects. For Each selected Learning Object *SAA* stores information about its use like download status, start learning timestamp, utilization rate and so on. A *session log* consists of a set of *user actions.* The ontology of a MASEL *SAA* is described by the DTD shown in Figure 3.

```
<!ELEMENT StudentAssistantOntology (User-
Profile,lom*)>
<!ELEMENT UserProfile (Employee, Learnin-
gHistory, LoginInformation, SessionLog*)>
<!ELEMENT LoginInformation EMPTY>
   <!ATTLIST LoginInformation
      Username CDATA #REQUIRED
      Password CDATA #REQUIRED
   >
<!ELEMENT LearningHistory (SelectedLO*)>
   <!ATTLIST LearningHistory
      Employee IDREF #REQUIRED
   >
<!ELEMENT SessionLog (UserAction*)>
   <!ATTLIST SessionLog
      SessionId ID #REQUIRED
   >
<!ELEMENT UserAction EMPTY>
   <!ATTLIST UserAction
     ActionDescription CDATA #REQUIRED
   >
<!ELEMENT SelectedLO
(lom,LearningObjectStatus)>
<!ELEMENT LearningObjectStatus EMPTY>
   <!ATTLIST LearningObjectStatus
     Downloaded (true|false) #REQUIRED
     StartLearningTimestamp CDATA #IMPLIED
     UtilizationRate CDATA #IMPLIED
   >

<!-- lom is defined in IMS Specification  -->
```

Fig. 3. The DTD describing the Ontology of a Student Assistant Agent

2.4 The Learning Paths Agent

Provided Services. A Learning Paths Agent deals with creation of learning paths able to fill the competence gaps of an employee Em_i supported by a Student Assistant Agent SAA_i. *LPA* provides SAA_i with the following services:

- creating a *pre-assessment* test allowing to evaluate a specific competence gap;
- selecting and composing the suitable Learning Objects to build a learning path;
- enriching and modifying a learning path according to feedbacks user provides for example by answering tests and assessments.

Moreover *LPA* possibly informs CCO Assistant Agent about the lack of some Learning Objects needed to build specific learning paths.

```
<!ELEMENT LearningPathOntology (lom*,SkillMap, LearningHistory*)>

<!-- lom is defined in IMS Specification  -->
<!-- SkillMap is defined in SMA Ontology  -->
<!-- LearningHistory is defined in SAA Ontology  -->
```

Fig. 4. The DTD describing the Ontology of a Learning Paths Agent

Ontology. The ontology of a generic *LPA* consists of an XML document storing information about the *skill map SM* of the organization, the Learning Objects available for building learning paths and, for each employee Em_i, her/his *learning history* lh_i. The ontology of a MASEL *LPA* is described by the DTD shown in Figure 4.

2.5 The Content Agent

Provided Services. A Content Agent *COA* is specialized in managing a Learning Object Database. *COA* assists a generic Learning Paths Agent *LPA* in building a courseware and a generic *CCO* in managing learning contents providing the following services:

- inserting, deleting and updating Learning Objects and relative descriptions;
- querying the Learning Object Database by suitably accessing Learning Object Metadata (*LOM*).

Ontology. The ontology of a generic *COA* consists of an XML document storing information about the Learning Objects currently stored in the Learning Object Database. Each Learning Object is described through an XML document (*lom*) validated with respect to an XML Schema established by the IMS standard [2]. The ontology of a MASEL *COA* is described by the DTD shown in Figure 5.

```
<!ELEMENT ContentAgentOntology (lom*)>

<!-- lom is defined in IMS Specification  -->
```

Fig. 5. The DTD describing the Ontology of a Content Agent

2.6 The CCO Assistant Agent

Provided Services. A generic *CCO* supports a Chief Content Officer in managing a Learning Object Database providing the following services:

- inserting, deleting and updating Learning Objects and relative descriptions. This task is carried out in cooperation with the Content Agent;
- showing, for each employee, the learning activities history. This task is carried out in cooperation with the User Profile Agent.

Ontology. The ontology of a generic *CCO* consists of an XML document storing information about the *skill map SM* of the organization, the Learning Objects available for building learning paths and, for each employee Em_i, her/his *learning history* lh_i. The ontology of a MASEL *CCO* is described by the DTD shown in Figure 6.

```
<!ELEMENT CCOAssistantOntology (lom*,SkillMap, LearningHistory*)>

<!-- lom is defined in IMS Specification  -->
<!-- SkillMap is defined in SMA Ontology  -->
<!-- LearningHistory is defined in SAA Ontology  -->
```

Fig. 6. The DTD describing the Ontology of a CCO Assistant Agent

2.7 The User Profile Agent

Provided Services. A User Profile Agent stores useful information about all the registered users. For instance: personal data, log-in data, current and past learning activities. A *UPA* provides the following services:

- managing users log-in to the system;
- managing users profile information;

– updating the competence levels of a employee according to her/his learning activities. This task is carried out in cooperation with the Student Assistant Agent, associated with the employee, and with the Skill Manager Agent.

Ontology. The ontology of a generic *UPA* consists of an XML document storing the *profiles* of the registered users. The ontology of a MASEL *SAA* is described by the DTD shown in Figure 7.

```
<!ELEMENT UserProfileOntology (UserProfile*)>

<!-- UserProfile is defined in SAA Ontology  -->
```

Fig. 7. The DTD describing the Ontology of a User Profile Agent

3 An overview of MASEL behaviour

As previously pointed out, a MASEL multi-agent system consists, at least, of one CLO Assistant Agent, one Skill Manager Agent, one Content Agent, one Learning Paths Agent, one CCO Assistant Agent, one User Profile Agent and *n* Student Assistant Agents SAA_1, SAA_2,…, SAA_n. Figure 8 shows the architecture of a generic MASEL multi-agent system. Each box represents a MASEL Agent and each arrow between two boxes indicates cooperation between the two represented agents.

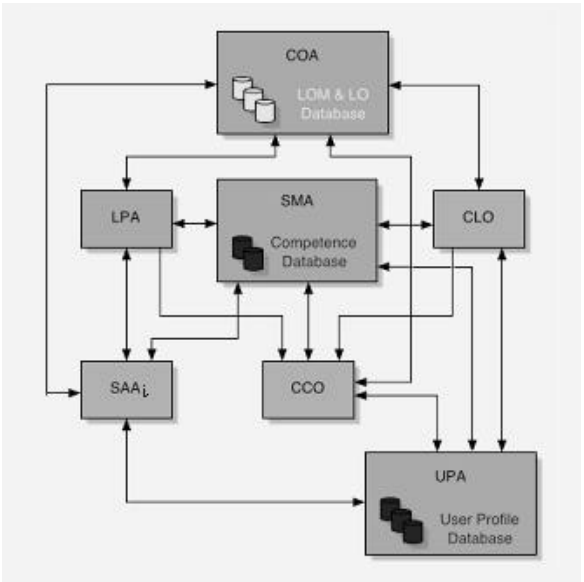


Fig. 8. A diagram showing MASEL architecture

A CLO Assistant Agent supports Chief Learning Officer in managing the *skill map* and in defining a learning strategy in terms of roles and competencies required for the organization. This task is carried out in cooperation with the Skill Manager Agent. A *SMA* stores the information, previously inserted by a *CLO*, about roles, associated competencies and employees. Moreover, for each employee Em_i, *SMA* manages the information about Em_i role and Em_i current competence levels. A Chief Learning Officer can require her/his *CLO* to suggest the most suitable employees for taking a specific role and can assign a specific role to an employee, in such a case *SMA* evaluates the employee competence gaps according to the assigned role.

When Em_i logs in her/his Student Assistant Agent SAA_i shows the gaps between her/his current competencies and the competencies required for her/his role in the organization; these are specified along with priorities or/and temporal constrains related to the competencies that have to be acquired. This task is carried out in cooperation with the Skill Manager Agent. When Em_i decides to fill a specific competence gap, say $Cgap_k$, SAA_i asks the *LPA* to perform three tasks:

- creating a *pre-assessment* test able to evaluate $Cgap_k$;
- selecting and composing some Learning Objects $\{LO_{k1},\ldots,LO_{kn}\}$ in order to build a learning path Lp_k;
- enriching and modifying Lp_k according to feedbacks user provides (for instance by answering tests and assessments).

These tasks are carried out by *LPA* in cooperation with the Content Agent *COA* that provides *LPA* with the suitable Learning Objects. Moreover *LPA* may inform CCO Assistant Agent about the lack of some Learning Objects needed to build specific learning paths.

SAA stores all the information about current learning activities of the student. Periodically these information are sent to the User Profile Agents. Thus, eventually, *UPA*, in cooperation with *SMA*, updates the current competence level Ccl_k of Em_i according to her/his learning activities.

4 Conclusions

In this paper we have presented MASEL, an XML Multi-Agent System for E-Learning and Skill Management. MASEL is strongly based on a continuous interaction among involved agents; such an activity is facilitated by the choice of XML for both representing agent ontologies and handling data exchange. MASEL has been thought as an attempt to exploit XML agents and their benefits in E-Learning research. Agents in MASEL have been designed to perform the following tasks: *(i)* supporting Chief Learning Officers in defining roles, associated competencies and knowledge level required; *(ii)* managing *skill map* of the organization; *(iii)* measuring human resources

competence gaps; *(iv)* supporting employees in filling their competence gaps as related to their roles; *(v)* enriching a given courseware or creating personalized learning paths according to feedbacks user provides in order to optimize the acquisition of needed competencies; *(vi)* assisting Chief Learning Officers in choosing the most appropriate employee for a given role. Presently we are working towards the construction of a prototype tool implementing MASEL using *JADE* (*Java Agent DEvelopment Framework*). *JADE* [3] is a software framework fully implemented in Java language. It simplifies the implementation of multi-agent systems through a middle-ware that complies with FIPA specifications and through a set of tools that support debugging and deployment phases. As far as future work is concerned, we plan to extensively test our system on real application cases in order to validate the effectiveness of the approach. In addition, we plan to increment the cooperation among the agents of the system by extending it to other tasks like *full fledged team building* problem and definition of career path for employees taking into account gaps between possible future roles and current competencies.

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