Implementing Agents for a Collaborative Online Learning Environment

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Abstract: This paper discusses the main lines used to model intelligent agents that will operate in a Collaborative Online Learning Environment – COLE. The aim of COLE is to evaluate the contribution that Information Technology and Multiagent Systems can bring to the discussion about new adult learning processes. The work hypothesis is that online environments can better handle the huge mass of data related to human interactions in social learning processes than the face-to-face educational ones. Acquiring and managing expanded sets of data has been an obstacle to implement educational practices that consider students in broader dimensions, far beyond content assessment. Elements of the Social Learning Theory, specifically concepts from the Communities of Practice base COLE implementation. A brief description of Project Based Learning – PBL and portfolios (here conceptual maps) give elements to understand the project approach. The SAAS method, used to identify the agents is described. Use cases related to the "Librarian Agent" and the "Portfolio Agent" are presented and windows related to the "portfolio" and "active reading annotation" services illustrate the work.

Keywords: Distance Education, Online Collaborative Learning, Learning Environments, Multiagent Systems.

1. Introduction

Great availability of fast evolving information characterizes nowadays society. Global economy requires highly prepared professionals, used to IT and aware of life long learning [1].

Educational Councils have to reason about the new society requirements (students shall find a place in this moving economy), but, they also have to draw proposals that induce the development of critic, autonomous and creative citizens.

Pierre Levy makes three remarks: 1) the high rate of creation and renew of knowledge makes the competencies one has in the beginning of his/her professional life become obsolete in few years; 2) In the new nature of work the transition of knowledge grows continuously and working is equivalent to learning, transmitting and producing knowledge; and 3) the cyberspace bears intellectual technologies that amplify, exteriorize and alter many human cognitive functions like: memory (database, hypertexts, digital archives of all sorts), imagination (simulations), perception (digital sensors, tele-presence, virtual realities), and reasoning (artificial intelligence, modeling of complex phenomena) that increase exponentially the potential of collective intelligence of human groups [2].

A way to motivate learning is creating situations that emphasize the students' engagement in meaningful practices, letting them identify their own learning trajectories, and emphasizing their involvement in actions, discussions and reflection. Engagement is an active involvement in mutual processes of negotiation of meaning. It occurs through shared stories of learning, relationships, interactions and common practices. It can be described as a triple process that includes the conjunction of continuous negotiation of meaning, the tracing of trajectories and the revealing of stories of practice. For an effective leaning process to occur it is necessary a mutual engagement toward a common objective [3].

Learning is not simply the construction of memory, habits or getting degrees, but the construction of its own identity. Information stored explicitally is a little part of knowledge; this involves active participation in social communities [ibidem]. Thus, the traditional teaching is not so productive once the classrooms detached from the world make more difficult to students to experiment meaningful forms of identification.

For Moran, an effective education process collaborates so that teachers and students remain in a continuous learning process, helping them in the construction of identity, of personal and professional paths. They can develop the ability of comprehension, emotion and communication that allow them to find their own personal, social and

working spaces. Such processes offer resources so that students become productive and accomplished citizens. For him, if the educational programs were adapted to the students' needs and with connection to the quotidian, there would be more advance in learning [4]. This statement was formerly pointed by Vygotsky, who affirmed that collaboration between peers helps the development of problem solving strategies and general abilities through a cognitive implicit process of interaction and communication [5].

This paper proposes an online learning environment based on a multiagent system. The environment, besides focusing on professional competencies, also enables the development of social competencies such as collaboration/cooperation, negotiation, evaluation, selection of information, continuous learning, ethical behavior and proactive attitudes. We assume that professionals formed in an environment like this one will be better prepared to follow the evolution of their careers and practice of their citizenship. The PBL (*Project Based Learning*) approach is used, where students must work in groups and propose solutions for challenges they face. In COLE, the PBL is the motivating element that catalyzes the learning process and motivates the interaction [6].

The section 2 presents a comparison between the concepts of collaboration and cooperation, besides the definition of PBL. In section 3 are presented the characteristics of a collaborative online environment. The section 4 presents the concepts related to the necessary agents for its implementation. Section 5 describes the use of the method used for agent definition and presents the characteristics of two agents inside COLE. The text is concluded with the considerations on work that has been developed.

2. Cooperation versus Collaboration

One can observe in the literature divergences on conceptualization of collaboration and cooperation. Although some authors use them as synonyms, there are the ones that approach it in different manners.

Matthews defends that *cooperative learning* occurs when the teacher is an active participant in the activities and is constantly intervening to answer questions, keeping students focused on the task and conducting the projects. Students' work is submitted and revised by the teacher. The students receive in advance formal training in necessary social abilities to work in group. In the *collaborative learning* the teacher does not monitor the group actively and the questions are solved by the students only. Each project ends with a discussion and the students are supposed to keep registries of what they were able to achieve. The collaborative learning includes the belief that the students already detain the necessary social abilities for the group work. Therefore no training is offered [7].

Matthews adds that both the cooperative and the collaborative learning are student-centered approaches that believe active learning as more efficient than the passive one. The teacher becomes a facilitator instead of a centralizer of knowledge. Both methods defend that the participation in activities of small groups develops abilities for superior level thoughts and improves individual abilities to use the knowledge. When students articulate their own ideas in public improves the ability for reflecting on their own learning processes [ibidem].

The COLE environment incorporates both the collaboration and the cooperation concepts. It search for resources that allow students to develop social abilities in the same time they study the content of a given syllabus. And more relevant, it search for tools that help teachers to follow, support and evaluate the students' development in broader dimensions.

Project Based Learning – PBL – is a methodology related to collaborative learning. It focuses on problem-solving or case studies. Although such approach may be applied individually, in the group work the output is better inasmuch as in real life the solution of a problem is rarely achieved without the of someone else's assistance [8].

COLE proposal considers that the mere existence of interactive tools in online leaning environments (e.g.: e-mail, discussion lists, forums or chat-rooms) are nor sufficient to configure a collaborative/ cooperative environment. According to the Social Theory of Learning [9] and [3], human beings take part in social activities motivated by their continuous need for construction of identity. So, every action has a meaning in the sense that people recognize themselves and are recognized by the others.

In this sense, activities where collaboration /cooperation may be identified are those that, besides common goals, shared vocabulary or possibility of interaction, also present mutual engagement. When there is engagement, the social relations tighten and people assume roles and values recognized by everyone in that community. Roles and values allow people to project and reflect on their own identity. In this project we assume that collaboration/cooperation play a social role that becomes a human value only through practice.

3. Collaborative Online Learning Environment

The Collaborative Online Learning Environment – COLE – has its grounds on the concepts of PBL to implement a computational environment that allows collaboration/cooperation. However, for the teachers to be effectively able to assess the students, taking into account the progress of each one and the work conducted by them, we adopted the concept of portfolio.

Portfolios are used in this context to represent the work done in structures that store the history of the student's learning. *Hypotheses*, *ideas* or *arguments* aroused and refuted are also kept in the portfolio so that later on the evaluator can clearly visualize the path the student walked in his search for knowledge. Figure 1 presents a conceptual model of the relation between the elements of an *idea* (to be represented in a portfolio management module).

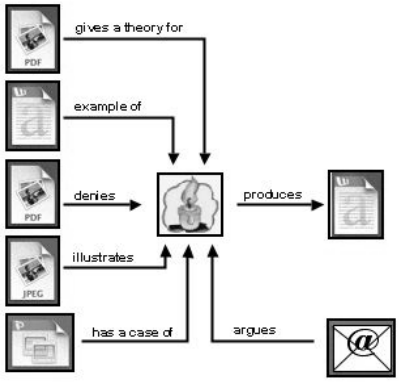

Figure 1: Elements that constitute an idea

The objects composing the portfolios carry in themselves an own semantic, whose meaning is shared by all users of the environment. Each portfolio may contain the following objects:

Ideas: a portfolio may have several ideas. As the student moves forward in his project, he can bear an idea that later may be refuted. Furthermore, the intellectual product of an idea may motivate a new idea that will be developed as a sequence of the former one.

Hypotheses: the starting point of the development of an idea is the arousing of a hypothesis, textually described by its author (student). A hypothesis is represented through an icon, that when activated opens a screen for text edition. Each idea may have one hypothesis at most.

Arguments: documents or e-mails that help bear a hypothesis. They are linked to the hypothesis through arches of semantic value (e.g. exemplifies, defends, refutes, fundaments, etc).

Collaborations: the interactions may happen at any moment in the development of the project. When a student feels difficulty in any topic or identifies in the environment some mate with problems in the development of his tasks, he can either solicit or offer help. The student may register in the *idea* the collaboration he/she received from another student through an icon that when activated shows the content of the discussion and the kind of interaction that happened.

Intellectual Products: the result of the development of a hypothesis is called Intellectual Product. It is represented through an icon related to the hypothesis, that when activated opens a document where the student can put his conclusions or solutions regarding the work developed. In case a idea generated by a student is negotiated and accepted by the other members, its intellectual product becomes a document in the base of documents that later on may be referenced as an argument in other group's ideas.

COLE presents two instances of portfolios:

Individual Portfolio. It is where the student registers his work, his hypotheses and arguments that bear them. Each argument is the relation between part of a document and a hypothesis. The documents remain in the virtual library and have punctuation, according to its relevance. When the student uses a document as argument, he adds a second punctuation, qualifying the contribution of the argument for the construction of the idea in question.

*Collective Portfolio***.** Stores the ideas (hypotheses and arguments) resulted from individual portfolios that were judged by the majority of the group as potential for the solution of the problem. The student sends his proposal idea to the other members. These ones comment on it, make suggestions and finally decide if it will be inserted in the collective portfolio.

For Santoro et al, a computational environment for cooperative learning based on projects must be flexible, allowing teachers and students to profit from the computational technology and configure different cooperative projects according to desired specific characteristics. The same authors propose common elements to the environments for cooperative learning found in literature and that can reinforce the process of cooperation in PBL environments [10]. To effectively become collaborative/cooperative, COLE environment assumes as necessary the implement-tation of most elements presented by the authors [6].

4. Agents and Multiagent Systems

Before defining what a multiagent is, it is opportune to deepen the concept of agent. The authors involved with the theme have offered a variety of definitions, each with different explanations for the use of the word "agent" [11]. In this piece of work, the word agent is used to indicate a computational system situated in an environment, with the capacity of acting autonomously in this environment to reach its own goals [12].

Despite the variety of definitions found for the term agent, some characteristics are common. Wooldridge and Jennings present the following basic characteristics of an agent [13] [12]:

Autonomy: be able to execute tasks without human interference or from other agents, and have some kind of control over its own actions an own internal state;

Social Ability: be able to interact with the other agents or people to solve its problems or help in the solution of others' problems;

Reactivity: be able to perceive its environment and respond according to changes;

Pro-activity: agents must not simply respond to the environment, but must "take the initiative" to reach its goals.

Other attributes as mobility, cooperativeness, communicability and learning also appear in the literature [15]. An agent may present a subset of the cited characteristics. However, that interferes in its abilities. Nwana proposes the following categorization of agents [16]:

Collaborative Agents: emphasize the autonomy and cooperation (with other agents) so that they can accomplish the tasks for its owners;

Interface Agents: emphasize the autonomy and learning for the accomplishment of tasks for its owners;

Mobile Agents: are able to travel over large nets, like the intranet, interacting with other hosts and storing information for itself and its owners, coming back after having solved its tasks;

Agents of Information/Internet: play the role of managing, manipulating and collecting information from many distributed sources;
Reactive Agents: act and respond in a stimulus-response manner to represent the environment they are inserted in;
Hybrid Agents: constitute a combination of two or more categories in a unique agent.
When two or more agents are present in a system, this system is called multiagent. Multiagent systems are computational systems where two or more agents interact or work together to execute a set of tasks or satisfy a set of goals [17]. "[...] a multiagent system is composed of agents that share a common environment" [15].
According to Sycara, a multiagent system owns the following characteristics: each agent has information and incomplete capacities for the solution of problems, that is, have a limited view; there is no global control; the data are decentralized; the computation is asynchronous [17].
Additional characteristics such as: ability in promoting bulkiness and efficiency, ability to allow the inter-operation with the legacy of existing systems and ability to solve problems where date, expertise or control are distributed are presented in [ibidem] [18] as relevant factors concerning the growth of the multiagent system area.
Some reasons for the use of multiagent system in the implementation of COLE are: complexity of the processes involved; necessity of asynchronous and distributed computation; information naturally distributed; facilitation of users' work.
In the following section some of the proposed agents are detailed.

5. Implementation

The implementation of COLE is a challenge for the researchers involved in the project, because it does not deal about the informatization of an existing practice, but the development of a learning environment capable of expanding the traditional learning processes potential.
For the analysis and identification of agents we used the SAAS method (Service Analyses for Agent Systems) [20], [21], that aims at aiding in the process of analysis and specification of agents.
The SAAS method is divided into 8 steps: (1) collecting of information; (2) classification of activities/resources; (3) validation; (4) description of services; (5) writing of scenarios; (6) construction of models; (7) identification and (8) synthesis of competencies;
Steps 1 and 2 constitute the collecting of information through interviews and organization of data in form of tables and graphs. *Steps 3 and 4* determine the potential services that could be implemented. Steps 5 and 8 correspond to validation of the work accomplished in the previous steps. For further information on the SAAS method consult [20][21].

Application of the SAAS method. As COLE is a learning environment to test new practices, steps 1, 2 and 3, the ones that document how the work is accomplished, were not applicable.
Step 4: Description of services. The services identified by the designers are compared. In case of disagreement they are rewritten and finally restructured in a service table. Six out of the fifteen services initially identified are presented in table 1.

Table1. Some services identified for COLE

ID	Service	Tea-cher	Stu-dent
S1	Initialize/finish project	X	
S2	Enable student/Organize teams	X	
S3	Edit portfolio (insert argument, abandon argument, insert production)		X
S4	Propose idea for the group		X
S5	Insert document in the data base	X	X
S6	Add keyword/definition	X	X
S7	Evaluation of ideas (indication of idea acceptation probability in case of group evaluation submission)		X
S8	Determination of accepted and refused ideas profiles by the group.	X	X
S9	Research of keywords in the library	X	X
S10	Management of massages exchanged by students during the development of an idea	X	X
S11	Overview of student's performance (individual portfolio)	X	X
S12	Overview of student's performance (collective portfolio)	X	X
S13	Overview of teacher's performance regarding students' follow-up.	X	
S14	Mark management (active reading of documents that will be used as arguments inside ideas)	X	X
S15	Management of messages exchanged during negotiation phase	X	X

Step 5: Writing of scenarios. We write scenarios that involve the services listed in the table. The main objective of the scenarios is to permit the users and the designers a common document that may be discussed by the group and allows the refining of the role of the services. The scenarios are written by the designer of the agent that will contain the service. The scenarios are presented for a group of users that correspond to the profile of the service. The group of users refines the scenarios by adding and removing parts. An example of scenario for the COLE is presented as follows.

Example of a part of a scenario: Edit Portfolio
Leandro is a registered student in the COLE system and at present takes part in projects A, B e C. The project A is a two-week course and projects B e C are

three-week ones. Leandro needs to edit his portfolio in project A because there are only four days left for its closing. The portfolio contains at present 2 complete ideas. Leandro wants to develop one more idea for his portfolio. After going through the identification control, Leandro selects the project he wants to work on. COLE presents the possible options. Leandro chooses "edit portfolio". COLE presents Leandro's portfolio.
Leandro> Add a new idea.
COLE> Type the text of the new hypothesis.
(Leandro types the text of hypothesis and confirms. COLE creates the new structure of idea in the portfolio).
Leandro> Add an argument to the hypothesis.
(COLE presents a list of documents previously selected by Leandro, but Leandro wants to look for a new document).
Leandro> Search for documents.
(COLE opens a search window so that Leandro can enter the data for the query: author, name and keywords. Leandro types part of the document name and validates it. COLE presents the documents found. Leandro selects the document he wants to read).
....
Step 6: Model. The scenarios generate a set of possible windows for COLE. They are presented to the teachers and students so that they can contribute for the refining of the service in an objective fashion (suppressing or adding buttons, field, etc).
Step 7: Identification of competencies. The identified services, through the windows consolidated by the group, require sets of specific competences to be executed. These competences are named, described and their input and output parameters identified.
Step 8: Synthesis. Once the basic set of services is obtained (with its respective competences) one goes on to analyzing the redundancy of competences in distinct services and the viability of its implementation in new secondary services. Table 3.2 presents the agents initially identified for the COLE environment.

Table 2. Initial agents of COLE

Service	Description of Agent
S1, S2, S3, S4	**Portfolio Agent –** aids students in the representation of their ideas in the portfolio. (AgPort).
S5, S9, S10, S15	**Librarian Agent** – aids the students and teachers in the research, insertion and indexation of documents in the data base (AgBib).
S6, S7, S8	**Dictionary Agent** – responsible for the control of keywords and their respective definitions (AgDic).
S12, S13	**Evaluation Agent** – aids the teacher in the students' learning process evaluation (AgAva)
S11	**Balloting Agent** – aids the students managing the ballot process when they submitt ideas to integrate the group portfolio (AgVot).
S4, S15	**Negotiation Agent** – coordinates and manages the idea balloting process and the inclusion of ideas in the group portfolio. It builds profiles of winner and loser ideas in the group portfolio (AgNeg).
S10	**Communication Agent** – manages the messages exchanged among participants according to the work context (during the construction of an idea or during a negotiation…) (AgCom)
S14	**Marking/Annotation Agent** – Manages the database related to the text marks made by the participants in the documents they read (AgMar).

The Librarian and Portfolio Agents. Both the Librarian and Portfolio agents are being developed. The Librarian agent is being implemented in a server where the documents will be stored. The Portfolio agent will be placed in the students' machines so that they can work on their portfolios offline. Figure 2 and Figure 3 present examples of use case diagram for the Librarian and Portfolio Agents.

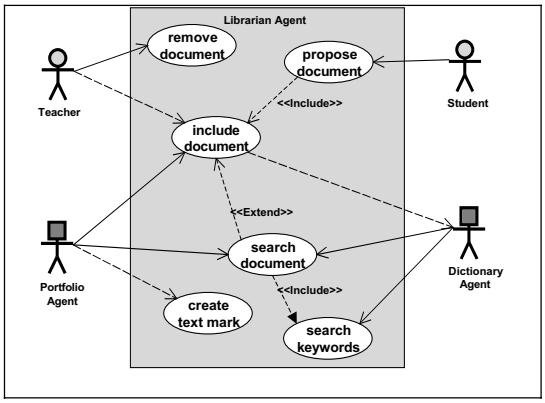

Figure 2: "Librarian Agent" use case diagram

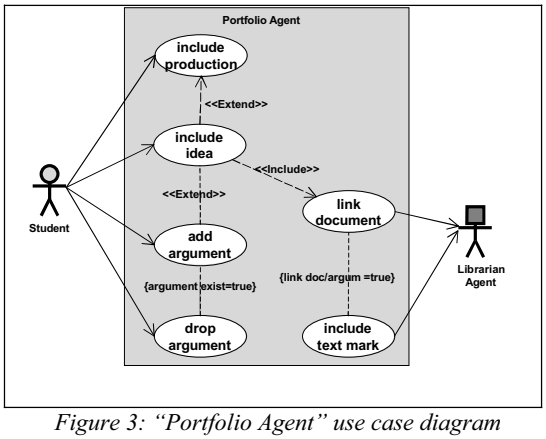

Figure 3: "Portfolio Agent" use case diagram

The communication between agents will be asynchronous. The users will be students and teachers, geographically scattered, connecting to the environment at different schedules.
COLE will be implemented in a Linux environment. UDP/IP (User Datagram Protocol/ Internet Protocol) will be used to exchange messages between the agents in a LAN. An e-mail server will allow agents to communicate through Internet.
Initially, the implementation of agents will be made in JAVA and the agents' knowledge bases will be made with XML (Extensible Markup Language).

Figure 4 shows the marking/annotation window service. One notices a special toolbar in the text editor application. The reason is that documents belonging to the virtual library are not supposed to be changed. The reader can mark the paragraphs that seem to be relevant to his/her hypothesis by using the marking menu. Each color has a semantic meaning (e.g.: gives details of, complements, concludes about, diverges from, criticizes, describes, gives example of, gives theoretical basis, illustrates, justifies, inquires, denies, reinforces, validates). Students can do as many marks as they want in a document; all of them are stored separately. By doing so, the same document can be used several times as argument in one idea, each time with a specific meaning. Students can also make annotations in a given document (text in the right margin) while working in a document. Only marks are used as arguments and can be viewed through the arguments icons of the ideas.
As a prototype, the marking/annotation service was implemented using Visual Basic macros.

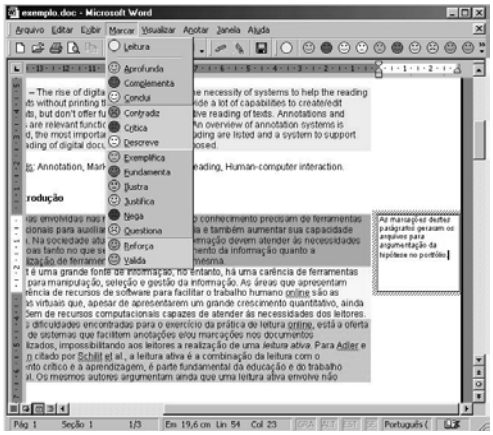

Figure 4:A text document with four text marks and one annotation.

Figure 5 shows the individual portfolio editor. Candle icons represent hypotheses, brick icons represent arguments and brick walls represent intellectual products.
As one can see in Figure 5, ideas are structural elements that allow students to explicit how they plans to solve the problem they have in hands in a meta level.
Inside a individual portfolio ideas can inform when they were started, when they were finished, the number of arguments they have, the kind of media the arguments have, the level of authority the arguments have, how the student relates the arguments with his/her hypothesis, the student flow of work through time, the paths made by the students during the learning process, the ideas that evolved and the ones that were aborted. They can also identify reactive collaborative attitudes from colleagues (answering questions or remarks from the sender)
Inside a group portfolio ideas can inform about how students interact, showing pro-active collaborations attitudes. When a student suggests a new argument to reinforce an idea that was include in the group portfolio.

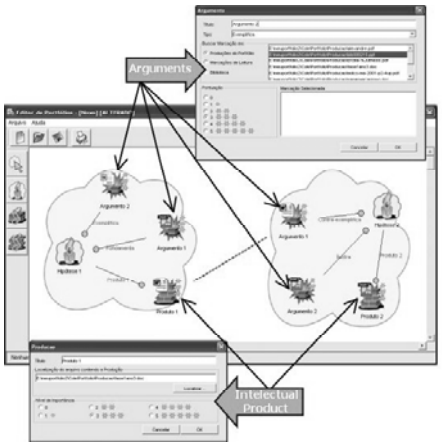

Figure 5:An individual portfolio with two secondary windows

The *intellectual product* of an idea can be marked and used as an *argument* for another *idea*. The dashed red line in Figure 4 shows visually the student's reasoning flow.
The Portfolio editor was implemented using: Java NetBeansIDE, Java SDK 1.4 (specially Swing e Graphics2D resources), JDOM (XML parser) and JFreeChart. JDOM was used to make the portfolios persistent and allow their easy recuperation.

6. Discussion

The computer supported collaborative learning model by proposed for COLE differs from CSCL (*Computer Supported Collaborative Learning*) environments found at present because it considers the engagement as crucial factor for the development of learning.
We assume in COLE that the existing services in a learning environment or the mere contact (study of syllabus) with its content are not sufficient to develop social values in its users. It is necessary that socially recognized practices in the activities stimulate the development of these values. Examples of this sort of practice are: the cyclic alternation of individual and collective work, the negotiation of ideas between students or the mutual evaluation.
Because it deals about a new proposal for interactive environments, COLE needs to be tested in both technological and pedagogical aspects. In the technological scope the tests refer to: (1) the way the environment is implemented, and (2) the use of SAAS for identification and specification of agents and services available in the environment. In the pedagogical scope we must verify through experiments if COLE fulfils the project proposals: develop both intellectual and social abilities.
The short-term application of COLE is lifelong learning courses.
COLE presents itself as an option of learning environment that incorporates the elements for the development of social competences beyond professional ones.
The computational approach through a multiagent system seems to be a viable option to develop learning systems that deal with huge amount of data in a complex fashion.

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