Machine Elearning – Learning Agents and UML for Elearning Settings

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Abstract**—**We study the interplay between machine learning, agents and object-oriented design, based on the Unified Modeling Language. The application setting is electronic learning or elearning. While extending our previous object-oriented experiences, we show how these diversified technologies can be integrated and applied to elearning settings. Thus we propose to describe an early attempt of bridging the gap between web-based learning and agents capable of learning from experience. The ultimate goal sought is the development of a fully-automated multiagent environment capable of assisting in the elaboration and delivery of highly-personalized educational material effectively for anyone, anywhere at any time while taking into account each elearner's personal profile and dynamic behavior during the elearning process. We rely on software engineering paradigm to describe strategies that go from early principles to fully-developed systems. For the time being, and as far as this paper is concerned, the attempt is to concentrate on the interaction between two core fields namely Unified Modeling Language (UML) and agents. The tangible results remain the integration of agents for elearning based on machine learning methods such as Decision Tree Learning, *AdaBoost*, and Ensemble Learning. An emphasis is made on fuzzy agents as a special case of soft computing methods used for profile personalization. Prospectively, much effort is still required to meet the actual challenges so as to scale up to real-life problems of any significant complexity.

Keywords**—** Advanced learning technology (ALT), E-learning, Decision tree learning, Web-based instruction, Multiagents, Machine learning, Fuzzy agents.

I. Introduction

Based on our previous experience in integrating different paradigms [1], [2], we intend to find a unifying framework within the area of elearning blending machine learning with multiagents, in the context of the Unified Modeling Language (UML). Over the last two decades or so, elearning has become an important feature of the Internet culture, although still in the making. Broadly speaking, elearning is synonymous with electronic learning, delivered *via* a broad array of technologies such as television, video tape, intelligent stand-alone tutoring systems, computer-based training, and the Internet. We are interested in web-based instruction either synchronously, *i.e.* in real-time, or asynchronously. Indeed, the available communication tools are either synchronous such as on-line classroom, telephone, videoconference, shared on-line document, audio / video chat or asynchronous such as email, fax, answering machine, newsgroups, forums and newspapers. The structure of a typical elearning course is based on readings and exercises from simple quizzes to projects, on-line discussion, forum participation, live chat (audio and video), time commitment, and video-conferencing, amongst others. Specifically, distance education takes place when teacher(s) and student(s) are separated by physical distance and technology such as voice, video, data, and print, often in concert with face-to-face communication and used to bridge the instructional gap [3].

On the basis of previous experiences [4], [5], [7], [8], [9], we show how emerging technologies can be applied, in theory and in practice, to elearning settings. Each individual learns in a different way and behaves differently when learning. Actual systems are poorly adaptable to individual behavior of the end-user. Therefore, a friendly-user multiagent-oriented environment is welcome to bridge the gap between user's behavioral features and pedagogical considerations, with helps on demand, while giving a living example of multiagents application to elearning [8]. The multiagent approach is used mainly for its flexibility and autonomy. This last concept can be summed up as the system's adaptability to different and unpredictable situations and generating rational, human-like decisions with no recourse to external help [10]. For so doing, we rely on soft computing methods such as fuzzy systems [11], on the one hand, and on machine learning methods, specifically Decision Tree Learning, *AdaBoost*, and Ensemble Learning, on the other hand [12]. The targeted result is a complete multiagent system to be built under constraints, partially known at the outset and progressively specified during the analysis phase and constantly refined during all design stages.

The paper presents the following structure. In the Section 2, we describe some of the most important elearning experiences undertaken in academia and industry based on the so-called Advanced Learning Technologies (ALT). The multiagent approach to problem solving in general, and with particular

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emphasis on elearning is discussed in Section 3. In Section 4, we describe a novel intellectual environment as the interaction between elearning and multiagents. Section 5 deals with architecture constructs. Section 6, reports the agents-free applications that we developed, complemented by the agents-based applications described in Section 7. A conclusion reports the main positive aspects of the proposed approach and hints to the possible future extensions.

II. Elearning Revisited

A. Academic elearning experiences

Nowadays, the advantages offered by elearning education are deeply rooted in the advanced methods of transmission of knowledge. It is widely accepted that the primary benefits of elearning in general, and that of web-based instruction in particular, over traditional classroom learning can be summed up in its economical cost and its self-paced quality, its availability anytime, anywhere, for anyone [13]. Numerous systems and web-sites are dedicated to elearning. We will only describe some of the prominent experiences.

1) The KSU-UFAS experience

The *UFAS-KSU project* is a joint project between Université Ferhat Abbas Setif, Algeria (UFAS), and King Saud University (KSU), and recently Qassim University, Saudi Arabia, [4], [5], [6], [7], [8], [9]. The aim in this project is the extensive use of Unified Modeling Language (UML) for the development of scalable distance education platforms. The core application is based on development of decision-support systems as applied to curricula development. One of the other important goals is to bring together on the same platform, instructors, course designers and course users for a better development, enhancement and use of instructional material. At the outset, the project was set out within the framework of the so-called *EUMEDIS* initiative, a large Euro-Mediterranean effort for the promotion of information technology in the European Union and 12 other Mediterranean countries,

[http://europa.eu.int/ISPO/intcoop/]. For research purposes, the project had recourse to the focal point of the *EUMEDIS* initiative in Algeria, namely the "Centre des Etudes et Recherche en Information Scientifique et Technique" *CERIST* [www.cerist.dz]. The present paper represents the logical continuation of this project.

2) The IEEE experience

Not only dealing with elearning, the Institute of Electrical and Electronic Engineers (IEEE) effort also addresses the issue of development of Web-oriented applications for research and commerce [www.ieee.org]. Moreover, IEEE has also moved to place its self-study courses on the Web, some entirely and others partially, in an effort to reposition its current array of products such as print-based self-study courses, videos, and CD-ROMs. One major challenge is to explore how IEEE and its Technical Societies can take advantage of the Web to promote their education programs as well as publications [14]. As an example of implementation of this policy for promoting the dissemination of knowledge, IEEE-Computer-Society has made available some 1,300 courses, more than 500 IT books for all members, 25 magazines, some 2,500 conferences archived since 1995, and 200,000 articles in both HTML (Hyper Text Markup Language) and PDF (Portable Document Format), at no additional costs through its so-called *elearning Campus*. Some of these on-line courses and tutorials are intended for professional certification with leading companies in the field such as Microsoft™, Cisco™, Oracle™, Sun™, IT security companies, project management companies, amongst others. IEEE also actively participates in the standardization process through its Learning Technologies Standards Committee. For more details refer to http://lstc.ieee.org/wg12.

3) ACM Experience

Likewise, The Association for Computing Machinery (ACM) is making similar offerings of on-line courses. The ACM Professional Development Centre [http://pd.acm.org] offers some 450 free on-line courses, 396 free on-line books for Professional and Student Members. The ACM Portal includes:

(i) ACM Digital Library (DL), a collection of 30 ACM publications including journals, magazines, conference proceedings, SIG (Special Interest Group) Newsletters, and vast archives representing over 1.2 million pages of text. The ACM-DL also contains full-text articles, some of which go back to 1950's as well as third party content with selected archives.

(ii) Guide to Computing Literature, a repository of 850,000 bibliographic citations, such as journals, proceedings, books, technical reports, and theses, extending far beyond ACM's proprietary literature. For more details see [www.acm.org].

4) MIT Open Course Ware (OCW) experience

The Massachusetts Institute of Technology (MIT) OpenCourseWare (OCW) represents an upgradeable database of courses. It intends to make all MIT courses available for the public *via* Internet. It is intended to participate in the advancement of knowledge and in the education of students in science, technology, and other areas of scholarship. In 1999, the Faculty considered how to use the Internet in pursuit of this goal, and in 2000 proposed OCW. MIT published the first proof-of-concept site in 2002, containing 50 courses. By November 2007, MIT completed the initial publication of virtually the entire curriculum, over 1,800 courses in 33 academic disciplines. Going forward, the OCW team is updating existing courses and adding new content and services to the site. At the time being (2008), 200 new and updated courses are scheduled each year. English is not the only language provided since other languages have been added since its first inception. Languages like Chinese, in 2003, and Thai, in 2006, have been added, along with other Mirror Sites like the first one established in Africa, in 2004 and other Mirror Sites can easily be added on demand. The main drawback of OCW lies in the fact that it is an asynchronous traditional database system, not allowing interaction with either an automatic teaching system nor with Faculty. Notwithstanding this point, OCW remains one of the educational sites that have the highest number of visits with around 2 millions per month, in 2007. For more details, see [http://ocw.mit.edu/].

5) The Fathom experience

Columbia University's for-profit elearning venture called Fathom, adopted a strategy of marketing eclectic courses to the public. Fathom's member institutions present their knowledge across every area of interest - from business to global affairs, from arts to technology. It offers free online seminars from Fathom's member institutions and course partners, also making available online education from research institutions. The available knowledge is presented in the form of lectures, interviews, articles, performances and exhibits by faculty, researchers and curators from all member institutions. Reference content spans practically all disciplines and fields of study. Among its member institutions, we can find the American Film Institute, British Library, British Museum, Cambridge University Press, Columbia University, London School of Economics, Natural History Museum, New York Public Library, RAND, Science Museum, University of Chicago, University of Michigan, Victoria & Albert Museum, Woods Hole Oceanographic Institution. So far, it has not been able to make profit yet. This seems to imply hat academic excellence does necessarily imply commercial ability. More details, in [w.columbia.edu ; www.fathom.com/].

6) The All-learn experience

Alllearn is a non-profit distance education company supported by three elite universities namely Oxford, Stanford and Yale [www.alllearn.org/]. At its beginning, the company offered on-line courses to the *alumni* of these universities only. Since August 2002, *Alllearn* delivers on-line courses for the general public. The directories feature over 12,000 websites with 19 different subject areas. Now courses in a dozen disciplines are available.

7) Other experiences

One of the earliest attempts to disseminate knowledge *via* electronic means such as televised programs remains the Open University in UK. The Open University was among the first higher education institutions to use a blended learning *i.e.* using more than one training space, usually face-to-face, instructor-led, and learning with web-based tools. The Open University study about elearners acceptance of web-based instruction shows that elearners still prefer using hard copy books to online technology especially when dealing with large amounts of course material. However, their study also shows that elearners make better use of course material when it is easily linked through a course web site [www.open.ac.uk]. Numerous institutions undertook similar Internet experiences worldwide.

B. Elearning solutions from IT Companies.

As a complement to the academic efforts described above, many elearning solutions are offered by Information Technology (IT) vendors. *U.S. News* and *brandon-hall.com* have teamed up to compile a directory of nearly 600 vendors that offer software, courses, tracking systems, and other electronic corporate training tool :

[www.usnews.com/usnews/biztech/elearning/]. We report the most prominent ones.

- IBM™'s elearning solution: the so-called IBM MindSpan™ Solution. [www-3.ibm.com/mindspan]
- Sun™'s elearning solution: the so-called WebCT™ [www.sun.com].
- Blackboard™'s elearning solution: Blackboard 5™ [www.blackboard.com].
- Sun™ Center of Excellence. Sun™ and Blackboard™ teamed up in 1999 to establish the so-called Center of Excellence open in March 2002 [http://dotedu.wisconsin.edu].
- Macromedia elearning Suite™ from Macromedia™ [www.macromedia.com/software/elearningsuite/
- GamaLearn, one of the few Arab companies established in Dubai, UAE, offers elearning solutions [www.GamaLearn.com].

C. Limitations of traditional elearning environments

More often than not, actual systems consider all elearners with a static behavior. For instance, all elearners are offered the same screen. Practically, all systems described above lack autonomy and have proved to be too monolithic to deal with the new expectations of individualized learning. Indeed, aspects such as data elearner personality, consistency and relevance become extremely important if one wants to have a truly-personalized learning. Besides, researchers in the educational field have shown that it is not possible to find a general strategy of teaching if we take into account human differences but it is rather probable to think that learning is an emergent result of rich and coherent dynamic interactions [15]. That is why we consider new vistas for educational technology based on multiagents and machine learning.

III. Multiagents

A. Brief definitions

If we accept that intelligence is concerned with rational actions, we can define an intelligent agent, or simply an agent, as a computational entity capable of perceiving its environment and that takes the best possible action in a given situation. An agent has the following basic properties:

- Acting on behalf of its users or other entities in autonomous fashion – a characteristics known as agency or autonomy.
- Behaving with some degree of proactivity and/or reactivity.
- Exhibiting some degree of learning, cooperation and mobility. When several agents work together on a single problem, we talk about multiagents [16].

B. From agents to multiagents

It is useful to distinguish two principal categories of learning in multiagent systems *i.e.* centralized learning, or isolated learning, and decentralized learning, or interactive learning. Learning is said to be centralized if the learning process is executed in all its parts by a single agent and does not require any interaction with other agents. With that, centralized learning takes place through an agent completely independent of other agents—in conducting centralized learning the learner acts as if it were alone. Learning is said to be decentralized if several agents are engaged in the same learning process. This means that, in decentralized learning, the activities constituting the learning process are executed by different agents. In contrast to centralized learning, decentralized learning relies on, or even requires the presence of several agents capable of carrying out particular activities [10].

In a multiagent system, several centralized learners that try to obtain different or even the same learning goals may be active at the same time. Similarly, there may be several groups of agents that are involved in different decentralized learning processes. Moreover, the learning goals pursued by such groups may be different or identical. It is also important to note that a single agent may be involved in several centralized and/or distributed learning processes at the same time. Centralized and decentralized learning are best interpreted as two appearances of learning in multiagent systems that span a broad range of possible forms of learning [17].

C. Software agents

1) What are software agents?

Although our work addresses the issue of multiagents applicability to elearning settings, we will concentrate on a specific type of agents, namely software agents, considered to be the most appropriate for the development of advanced human computer interface (HCI). The relatively short history of software agents can be traced back to the mid 1990's, a period of time that saw the interaction between HCI and artificial intelligence (AI) and lead to the new field of agent-based computing [18], [19]. Small-scale experiments with interface agents that learnt about their user [20], [21] and multiagent systems where simple agents interacted to achieve their goals [22] dominated the research. Such agent systems, called software agents, were all grounded in the real world, using proven AI techniques to achieve concrete results. Users can delegate a task to a software agent rather than explicitly ordering the agent to perform it, usually *via* distributed AI (DAI) techniques.

2) Types of research in software agents

The research in this field is diverse and multifaceted. We report the most representative results.

Academic research

Small-scale projects are undertaken with non-brand names while medium-scale research is undertaken in some academic institutions such as Carnegie Mellon University (CMU), Massachusetts Institute of Technology (MIT), the University of London, *inter alia*. The number of universities actively pursuing agent technology is quite broad and the list is ever growing.

Example: CMU's *visitor hosting system*. This system lies towards the “smart” end of the spectrum. In this system, “task-specific” and “information-specific” agents cooperate in order to create and manage a visitor’s schedule to CMU [23].

Applications in the tertiary

Many organizations now use agent technology.

Example 1: *The Chronicle of Higher Education*, a weekly Higher Education newsletter uses agents to delivers personalized emails based on user's static choices, [www.chronicle.com].

Example 2: Monster is a recruitment company that uses agents to deliver similar personalized emails [www.monster.ca].

Large Industrial applications

Large-scale research and development (R&D) projects are undertaken by large multinational companies such as Alcatel™, Apple™, AT&T™, BT™, Daimler-Benz™, DEC™, HP™, IBM™, Lotus™, Microsoft™, Oracle™, Sharp™, to name but a few. Obviously, the list is open. Clearly, these companies are by no means completely homogeneous, particularly if others such as Reuters™ and Dow Jones™ are added to the list. A short visit to the Web sites of these companies shows their diversified interest in the agent technology. The scope of the applications being investigated and/or developed is arguably more impressive: it really does range from the classic *i.e.* nearly agent-free to the moderately smart ones.

Example 1 : Lotus™ provides a scripting language in their Notes™ software which allows users to write their own individual scripts for managing emails, calendars, and set up meetings.

Example 2 : Microsoft™ agents are used for orthographic correction, for adding new words to user dictionary, for search of files on hard disks, among other applications [10].

3) Other motivations for using software agents

From the point of view of distributed artificial intelligence (DAI), software agents can be seen as a natural evolution from early multiagent systems, which in turn form one of three broad areas which fall under DAI, the other two being distributed problem solving and parallel AI. Hence, as with multiagent systems, they inherit many of DAI’s motivations, goals and potential benefits. For example, thanks to distributed computing, software agents inherit DAI’s modularity, speed, due to parallelism, and reliability, due to redundancy. Software agents also inherit AI properties such as operation at the knowledge level, easier maintenance, reusability and platform independence [24].

D. Educational multiagents projects

Multiagents have been applied to as diverse fields as auction/market, entertainment, email filtering, expert assistance, matchmaking, meeting schedulers, news filtering, recommender systems and Web. Several projects implement learning systems based on multiagents architectures. Some of them work on a generic platform of agents. Some educational systems include, but not limited to, the following.

- *JTS* is a web-based environment for learning Java language [25] based on a CORBA platform and using Microsoft™ agents. In this environment, students have access to their student models and they are able to change it, in the case they do not agree with the information represented.
- *I-Help* [26], a web-based application that allows students to locate human peers and artificial resources available in the environment to get help during learning activities. I-Help is an example of a large-scale multiagent learning environment [27].
- *Pedagogical agents* achieved interesting results by regarding the student motivations [28].
- *Companion agents* [29] act sometimes as mediators [30] within the learning process.
- *Tutor agents* [31] are usually related to student modeling and didactic decision-making.
- *Multiagents for distance education* are used to teach plane geometry for secondary education [32].
- *E-Creative design:* for stimulating the individual and group creativity in a design session using an e-research center in the field of mechanical engineering sciences as well as its development and integration in the existing national and international infrastructure [33].
- Systems integrating Web services [34].

Our aim is to enhance these contributions by adding a UML layer to the approach. UML has indeed grown to an industrial standard of software design because of its many advantages such as abstraction, inheritance, polymorphism, encapsulation, message sending, associations and aggregation [33], [www.uml-zone.com]. The way how UML is used in elearning design has been reported in previous works [4], [5], [6], [7]. Therefore it will not be described here.

IV. *ABED*: A Novel Elearning Environment

A. *Motivations: Emergence of a novel technology*

Our approach to elearning is an interactive synergy between traditional elearning and agents and represents an alternative methodology to actual elearning educational systems. We describe our **A**gent-**B**ased intellectual **E**nvironment for e**D**ucation (***ABED***) [8], [9]. The chosen agent-oriented methodology brings several advantages to the development of educational applications. Indeed, this methodology deals well with applications involving different entities with unique personalities such as elearners with various learning habits, instructors, course designers with different cultural backgrounds, while integrating different components of software, ranging from ready-made programs to customized development tools. On the other hand, agent engineering, together with technologies of networking and telecommunications, bring powerful resources and opens new vistas for research and development of novel educational systems. Finally, the economical results are expected to be considerable for all levels of education, worldwide.

B. *ABED Adopted Strategy*

In order to meet the requirements of the proposed environment, we follow the following strategy.

ABED Strategy

1. STRATEGY SET OUT
Follow specifications set out by Learning Object Metadata (LOM) and Sharable Content Object Reference Model (SCORM) standards.

2. AGENT-FREE STRATEGY
2.1 Study the process involved in design / development of non object-oriented agent-free systems [1], [2].

2.2 Repeat the previous step for object-oriented (*via* UML) of agent-free systems [4], [5], [6], [7].

3. AGENT-BASED STRATEGY
3.1 Study the process involved in design / development of non object-oriented agent-based systems.
3.2 Repeat the previous step for object-oriented (*via* UML) of agent-based systems.

4. AGENT-ON-DEMAND STRATEGY
Study the process involved in “parametrized” systems based on agents on demand.

C. *Compliance with standards*

In our proposed strategy, the first step is to follow specifications set out by standards such as Learning Object Metadata (LOM) and Sharable Content Object Reference Model (SCORM).

1) Elearning standards

Like any environment, our intellectual environment ***ABED*** is supposed to interact at one stage or the other with real-life systems such as operating systems, for instance. To be widely accepted, any environment has to comply with some adopted standards. For example, Internet as an environment cannot exist without standards like TCP/IP, HTTP, HTML, among others. Any scientific community needs its own standards, and elearning community is no exception to the rule. Standards help the community achieve key goals for all parties involved such as tool designers, content producers, consumers, and tool vendors. Generally speaking, the purpose of elearning interoperability standards is to provide normalized data structures and communications protocols for elearning objects and cross-system workflows. These standards can be organized into general categories like metadata (data about data), content packaging, learner profile, learner registration and content communication. [35].

2) ABED Contributions to LOM

What is LOM ?

[http://ltsc.ieee.org/wg12/index.html]

Learning Objects are defined as any entity, digital or non-digital, which can be used, re-used or referenced during technology-supported learning. Examples of Learning Objects include multimedia content, instructional content, learning objectives, instructional software and software tools, and persons, organizations, or events referenced during technology-supported learning. Examples of technology-supported learning include computer-based training systems, interactive learning environments, intelligent computer-aided instruction systems, distance learning systems, and collaborative learning environments. This standard is set out to specify the syntax and semantics of Learning Object Metadata (LOM), defined as the attributes required to fully, or adequately describe a Learning Object.

Example 1 : We propose to open a research track so as to apply multiagents in the use of metadata to support search, discovery, and retrieval of learning objects.

Example 2: use an agent mechanism to implement the guideline specified by LOM concerning the ability offered to learners or instructors to search, evaluate, acquire, and utilize Learning Objects.

3) ABED Contributions to SCORM

What is SCORM ? [www.adlnet.org/]

SCORM as a standard

The Sharable Content Object Reference Model (SCORM), devised by Advanced Distributed Learning (ADL) whose initiative is to act as a developer and implementer of learning technologies across the American Department of Defense (DoD). SCORM's aim is to foster creation of reusable learning content as "instructional objects" principally destined to Web-based learning. First released in January 2000, SCORM continues to update and expand the scope of the specifications through cooperation with industry, government and academic participants. SCORM describes a technical framework by providing a harmonized set of guidelines, specification and standards for deploying elearning.

Example 1: Because the standards do not specify how implementation is done, we propose to use the agent-oriented approach for implementation.

Example 2: for SCORM, use ***ABED*** strategy to develop an agent-based mechanism to implement the so-called content aggregation, a process whereby the self-contained SCOs are assembled into larger and coherent packages of objects.

D. Overall Operation in ABED

After complying with adopted LOM and SCORM standards, the second step in the ***ABED*** strategy is to study the process involved in design / development of non object-oriented agent-free systems, culminating with the use of object-oriented (*via* UML) of agent-free systems.

Agents are introduced in the third and fourth layers. Because of the specificity of the present article, we will concentrate on these last two layers. Although the elements each agent perceives in the environment change from one agent to another, all agents have a similar general behavior, described in four main steps:

· *Initialization*

The same environment is shared by all multiagents, by objects representing the solution constructed by the student, by objects describing the problem solved and simple objects representing candidate behavior. Agents are initialized in an inactive state, meaning that they cannot choose any action.

· *First interaction*

Agents perceive the environment. If an agent perceives in the environment the presence of elements represented, it becomes active. Since the agent is active, it is able to choose one set or more of candidate actions. On the other hand, if elements represented are not present in the environment, the agent remains inactive.

· *Next interactions*

Agents keep updating their states according to changes perceived in the environment. Action occurs in turns and active agents can choose eventually other relevant set of actions.

· *Stabilization*

When no significant changes are perceived in agent's states and actions, diagnosis is considered to be over. The state of an agent is conditioned by the presence of the elements perceived in the environment. An inactive agent has no right to choose actions. When an inactive agent becomes satisfied, it changes its state and becomes active. An active agent is able to influence other agents because of its activity. An active agent may become inactive again if at least one of the elements it represents is not present in the environment anymore.

E. Possible Applications of ABED

In terms of applications, our approach is significant in the following scientific / technological areas with implicit economical results in the medium and long run. Applications address the following issues.

1. To meet student needs and offer guidelines for better learning skills.
   Typical tasks include explicit guides for learning each specific material.
2. To offer novel methods for improving interaction and feedback between students and instructors.
   Typical tasks include employee workload balancing, availability, absenteeism, extra lectures and infrastructure availability for each elearner.
3. To improve design, planning and organization of courses and overcome computer limitations found in traditional elearning settings.
   Typical tasks include time table management, curriculum data, lecture frequency subject classification, linked courses, frequency, and schedules.

4. To identify instructional development and the key phases of the process including design, development, evaluation, and revision of courseware.
   Typical tasks include topics, contents, course duration, teaching patterns, automatic paper settings, and assisted courseware elaboration.
5. To set guidelines for agent-oriented evaluation of course delivery by specifying the types of evaluation.
   Typical tasks include but not limited to exam definition, schedule and frequency, subject allocation and classification, ranking, grades, promotion, absenteeism, and results dispatching.
6. To allow elearning institution management.
   Typical tasks include managing trusts, trustees and founders, institution branches / classification, infrastructure, definition and classification.
7. To point to common research questions such as agent-based learning *vs*. traditional elearning, the importance of multiagents, and cost *vs.* benefits.
   Typical tasks include contribute to a new area of research.

V. Architecture Considerations

A. Possible design specifications orientations

Elearning applications are varied. They include but are not limited to:

- Computer-assisted instruction (CAI) uses the computer as a self-contained teaching machine to present individual lessons.
- Computer-managed instruction (CMI) uses the computer to organize instruction and track student records and progress. The instruction itself need not be delivered *via* a computer, although CMI is often supported by CAI.
- Computer-mediated education (CME) describes computer applications that facilitate the delivery of instruction. Examples include electronic mail, fax, synchronous learning, asynchronous learning, and other Web applications, all based in traditional settings.
- We add here a novel area which we refer to as Autonomous Computer-Assisted Instruction (ACAI) based on agents emphasizing autonomy of decision-making in unpredictable settings. In this respect, *ABED* is ACAI-based.

B. Chosen Design Specifications

We are concerned with the design of an Autonomous Computer-Assisted Instruction (ACAI) environment that uses agents as a core mechanism. Agents use a PEAS structure (percepts, environment, actions, sensors). The idea is to generate actions from percepts in a given environment. We consider the following specific tasks destined to both asynchronous and synchronous modes.

- Specific tasks are concerned with the following:
  * To help in the definition of learning material with the actors involved (students, instructors, *ad hoc* specialists, staff), their ways of accessing to the system and their communication tools.
  * To define the type of tests and detailed content of courses concerned.
  * To manage changes (add/remove/update) in courses and actors properties.
  * To manage students' registration and pedagogical evolution.
- Design / develop / adapt associated tools and interfaces necessary for the task.
- Initially consider only a small, but upgradeable, range of activities to be undertaken by agents.
- Upgrade activities from non object-oriented agent-free to object-oriented agent-based systems.

C. Overall Tasks and Operation

To design a system is to define its structure and its organization in terms of its components interaction. The basic structure of our architecture is composed of the following modules.

- *Eadministration*: a module that provides tools for the administrative management of all the actors such as elearners, instructors, and staff, and others such as parents, *alumni*.
- *Ecourseware*: a module providing all tools necessary for courses taking, course elaboration and presentation, synchronously or asynchronously.
- *Forum:* module whereby the actors under the cover near-anonymity participate in the enhancement of learning process such as course content, delivery method, system operation, among others.
- *Newsgroup* module is provided for offline communication and accessible to all relevant actors.

All these subsystems are designed independently from course contents. This requirement implies that the contents structure has to be normalized so that it can be handled by the system's engine and in the same time has to be sufficiently flexible to maintain the themes diversity.

D. Examples of Agents' Structure

For initialization purposes, forms are filled by all relevant actors to give the system an initial behavioral model of each one of them. Of course, each actor has right to change the initial model provided at any time. This initial model is later used by agents to decide which action to begin with and how to alter it when constructing a new search strategy.

VI. Agent-Free UML-Based Tasks

At this level of development, the main issue is to model easily-maintainable object-oriented systems using the UML. The main tasks deal with the design, maintenance and reverse engineering of elearning systems using the UML [36]. As far as agent-free UML-based strategy, there two main phases:

Phase 1: Development of a comprehensive set of UML diagrams for a core Virtual University.

Phase 2: Implementation with state-of-the-art tools such as *IBM Rational Rose*™ or *.NET*™ Technology, allowing reverse engineering. We discuss both phases.

A. Applied UML

Specifically, we have developed a set of UML diagrams for a core Virtual University [37]. At the design level, the proposed architecture considers most of the processes involved in a Virtual University. This object-oriented model for an elearning setting will hopefully lead to the core of a complete Virtual University. The key design issues offered by the UML are readability, reusability, and above all, easy maintenance. Starting from first principles, we constructed a model by drawing most of the UML Diagrams. We concentrated on Use Case, Class, Sequence, and Collaboration Diagrams. The actual model offers the following facilities:

- Student registration, course management, course attendance, with automatic check-up.
- Various forms of self-assessment and examination from early courses up to graduation:
  * On-line, off-line, quizzes, full exam.
  * Automatic, semi-automatic, manual grading, according to examination mode.
- Other facilities to be added, because system is totally open, easily upgradeable.

B. Implementation with state-of-the-art tools

Specifically, we have successfully used a state-of-the-art CASE (Computer Assisted Software Engineering) tool, namely IBM Rational Rose™, coupled with Microsoft™ *.NET*™ Technology, namely *VB.NET*™*,* to implement part of the characteristics described in Section 6.1 above [38]. Maintenance issues are resolved through *IBM*™ *Rational Rose*™'s capability of handling reverse engineering. The targeted tangible result will be a complete fully-automated OOD-based system to be updated under novel constraints, partially known now, and progressively specified during all subsequent stages. Other facilities can be easily implemented because the system is totally open and supports reverse engineering facility.

VII. Agent-Based Development

The main issue addressed, at this level of design, is agent implementation based on soft computing approach and on machine learning methods [9].

A. Fuzzy Agent-Based Development

After a thorough study of soft computing methods in elearning, we use fuzzy logic for implementation of agent-based elearning system [39]. The result is the development of a system that automatically constructs unknown characteristics of an elearner. We applied two major aspects of artificial intelligence *i.e.* fuzzy logic which expresses the idea of imprecision characterizing human endeavors, and agent approach which describes reactivity, pro-activity and/or autonomy. Blending these two approaches in an elearning setting is a challenging task. The developed module has handled this problem with a great degree of success since it provides elearners with a fuzzy agent that helps in the construction of their profile automatically, on the basis of user past behavior. Furthermore, we used *ad hoc* tools for developing two levels with increasing complexity. For so doing, we applied the following design and implementation strategies:

1) Design Strategy

Fuzzy agent for elearner's profile construction
Design Strategy

Given the following data
- A set of courses displayed on a Web site.
- A set of disciplines to which these courses belong, with possible overlap.
- A number of visiting times any prospective elearner makes for consulting a given course Web page.

Find the following unknown characteristics
1. The membership degree of this specific elearner with respect to the given disciplines.
2. A profile for any elearner that is capable of predicting this elearner's future behavior *i.e.* what he needs or what he is planning to search for at a specific moment without letting him explicitly express his query.

2) Implementation Strategy

The first level, a traditional prototype, is implemented using Matlab™ [mathworks.com]. It is based on traditional non-object-oriented method. A second level uses an object-oriented method and is based on Microsoft™ *.NET*™ Technology, such as C#.NET™.

Fuzzy agent for elearner's profile construction Implementation

1. Traditional (Non-Object-Oriented) Method
   Development of fuzzy system with *Matlab Fuzzy Logic Toolbox*™ (www.mathworks.com)

2. UML-Based Method
   Development of a fuzzy system with *Microsoft C#.NET*™ Technology

3) Results

Any elearner using our system will be classified and advised on a unique basis. Thus, two different elearners using the system will have two different behaviors from the system, *e.g.* two different screens. This contributes to a more personalized elearning based on intelligent Graphical User Interface (GUI).

B. Agents and Machine Learning

At this level of design, the main issue considered here is the UML-based agent implementation of *ad hoc* advanced GUI.

The specific goal is to devise platforms for cooperation between UML and agents. Two directions of research have been explored. One of them concerns the development of general-purpose software implementing well-known machine learning algorithms. The other direction studies information retrieval of Arabic texts.

1) General Purpose Environment

We have studied the background of computational learning theory and we have developed a general-purpose software implementing well-known algorithms. We concentrated our efforts on entropy-based Decision Trees Learning (DTL), Ensemble Learning through *AdaBoost* and First Order Inductive Learning (*FOIL*). Furthermore, we draw a useful comparison between these different classes of algorithms [40]. The software can readily be integrated within an elearning setting provided that the relevant modeling is done.

2) Information Retrieval

a) Decision Trees Learning (DTL)

Decision Trees Learning (DTL) has also been applied to retrieve large corpora of Arabic Texts. The study concerns principally the structure of Prophetic Traditions '*Hadith'*, for information retrieval purposes [41]. The module is readily available for elearning application.

b) UML and Agents for Text Mining

A text mining system for Arabic language is modeled using the UML and the vector space model (VSM). The proposed system is a text mining called *AuthenTique* whose aim is to provide a list of Arabic narrative texts classified according to their degrees of similarity based on user query. Other implemented classic text mining methods in *AuthenTique* are TFIDF Weight (Text Frequency Inverse Document Frequency) and cosine measure [42], [43].

VIII. Conclusion

This paper reports some prominent facets of the concept of machine elearning – a synergy of machine learning, agents and object-oriented design as applied to elearning settings. As result of this interaction a novel agent-oriented architecture for elearning is proposed. We mean the so-called *ABED*. In addition to maintenance and modularity as key traditional concepts, autonomy is assured by multiagents which act for the benefit of the elearner considered here as a specific and unique entity. In our perspective, for each elearner and on the basis of some initial personalized information, a set of agents is dynamically allocated, according to the elearner's changing habits. Indeed, one of the challenges in an information-centered world, where human knowledge is the most valuable and scarcest commodity, it matters not only to make information available to people at any time, at any place, and in multiple forms, but also to reduce information overload by making information / knowledge relevant to the task-at-hand in accordance with the background of the users, their preferences, and habits. Through the mediation of our environment, elearners can enhance their ability to learn since they are indirectly helped during their entire search by very helpful agents that tune their behavior according to user's behavior, thus generating a human-like assistance during the elearning process. Future work might include the use of automatic concept formation capable of clustering instances and their associated description into a hierarchy of categories. As the actual results stand, we can assert that our work has made a useful contribution that we believe is relevant to modern educational technology. We still have to make a feasibility study so as to scale up to real-life problems of any significant complexity.

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