Modalities of using learning objects for intelligent agents in learning

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ABSTRACT. This article details some common characteristics of applications using intelligent agents as they relate to learning objects as software systems in delivering education. Readapting learning objects to different categories of learners constitutes a challenge for intelligent agents in their effort to provide a large scale of collaboration between different e-learning organizations. In order not only to have efficient access to learning objects, but also to offer to learners tutoring and mentoring help, collaborative and cooperative learning strategies, learning advancements, and social interactions, intelligent agents have been highly recommended by a number of researchers. This study investigates how these e-learning applications are designed, how students' differences are explored, and how these software systems are able to improve learning and teaching performances.

KEYWORDS: *Adaptive systems, Intelligent agents, Intelligent Tutoring Systems, Learning Management Systems, Learning objects, Learning services*

Introduction

Digital resources are already widely used in today's education, from early education to adult learning, from individual learners to large classrooms. The pace of growth is considerably fast. Especially for e-learning, there have been consistent leaps forward in the methods available to group, share, retrieve, and re-use curricular information through software applications. The Internet and multimedia resources have already become of great importance in learning (Lee et al., 2003). Separate technologies and organizations are merging, in order to deliver multi-faceted and multimedia channels for content that makes e-learning more effective. Many technology experts and teachers are working together to launch a set of methods and standards that enable easy re-use, recombination, and transfer of content between individuals, institutions, and countries. More specifically, the goals are:

a. Anywhere, anytime: delivering the learning content anywhere is a goal that underpins the e-learning paradigm. Also, in the case of asynchronous communication, the paradigm could be completed with the mention of the anytime characteristic.

b. Flexibility: course materials can be automatically adjusted, in order to be accessed by a large variety of devices, ranging from the workstations and desktop PCs to Personal Digital Assistants (PDAs) and mobile phones.

c. Personalization: the courseware's content delivers a unique learning experience, appropriate to the capabilities, skills, and needs of each individual.

d. Adaptivity: the system is not only able to profile users, but is also aware of changes.

e. Contextualization: the content is delivered considering a specific socio-cultural environment.

This study describes specific efforts to increase and diversify learners' access to e-learning opportunities. More precisely, it investigates specific ways in which digital resources are designed and stored into different systems and organizations, and automatically delivered to learners. How can the information be digitized, in order to be accessible, inter-operational, purposeful, and useful in storing different areas of knowledge? How can the digital resources be efficiently used to teach students? What kind of application should be designed, in order to explore digital resources better?

Since 1994, numerous organizations have been attempting to organize the curricular contents around the concept of Learning Objects (LOs). After many learning objects were collected, stored, and evaluated, the problem of efficiently using them for educational purposes is still a challenge. This investigation focuses on a specific direction - the use of Intelligent Agents (IAs) in processing learning objects. This paper is organized in five sections. After this introductory section, the second section summarizes the basic properties of intelligent agents and learning objects. In the next section, some of the educational perspectives brought by intelligent agent applications are presented. In the fourth chapter, software characteristics of educational applications using intelligent agents in manipulating learning objects, areas of research, and challenges of building these types of applications are discussed. The final section contains an overall perspective, discussing some drawbacks and main trends for intelligent agent applications using learning objects.

Main theories about learning objects and intelligent agents

This section presents the main concepts and the evolution of learning objects and intelligent agents concepts, considered separately. First, we will describe the concept of Learning Object (LO). There is no universal definition of learning objects. The learning object concept was first popularized by Wayne Hodgins, in 1994, during his activity at the Computer education Management Association (CeMA) working group, when he introduced the term 'learning object' (Polsani, 2003). The origin of this term started to be significantly related with the Object-Oriented Programming (OOP) paradigm (Bratina et al., 2002; Robson, 1999).

In time, the meaning of learning object changed. Learning objects became more concerned with the relevance of information, knowledge, and learning content than with the OOP aspects. A first attempt to standardize the notion of learning object was done by IEEE, the Institute of Electrical and Electronics Engineers. According to the definition of the IEEE Committee, a learning object could be any piece of information; it was not significant whether the information were digital or not. Therefore, this definition was considered too general (IEEE, 2002). For Quinn and Hobbs, a learning object is anything digital. In this case, all the content from Web pages and external devices would consist entirely of learning objects. It does not mention whether the information has an educational or pedagogical purpose or not. This definition was also found to be too broad (Quinn, Hobbs, 2000).

Better definitions result by considering the two related fundamental aspects of learning objects: the digital aspect, and the educational purpose (McGreal, 2004; Polsani, 2003). Sometimes, the definitions of a learning object are associated only with specific pedagogical ways of delivering the content. For instance, for CCI-Corporate Communications Interactive, a learning object is basically a pedagogical item consisting of text, image, sound, and multimedia. In order to be considered a learning object, the item should be "tight", self-contained, and have multimedia

teaching modules. For them, a typical module should comprise the following: an overview, a challenge, a lesson, a test, and a summary (CCI, 2001).
Today, there are many standards for learning objects, which give them a large audience to users. From the most widespread standards, we could mention:

a. IEEE Learning Object Metadata (LOM) was the first important standard created to the purpose of defining metadata for learning objects. Almost all implementations refer to this standard, although the model is considered now too simplistic and outdated (IEEE, 2002).

b. The Dublin Core Initiative (DCI) is a 15-element set, intended to define and facilitate the discovery of electronic resources. This format was widely accepted by a large number of librarians and digital libraries (DCI, 2006).

c. Educational Modelling Language (EML) was developed by the Open University of the Netherlands. It is characterized as "XML style" for defining different fields designed to provide presentations in education, and training processes (Koper, Manderveld, 2004).

d. Synchronized Multimedia Integration Language (SMIL) was developed by the World Wide Web Consortium (W3C). SMIL was designed to facilitate a wider authoring for multimedia presentations over the Web. This standardization was adopted by the World Wide Web Consortium, and is an easy-to-learn XML-style, allowing easy design of multimedia presentations (W3C, 2005).

e. Sharable Content Object Reference Model (SCORM) was introduced by the Advanced Distributed Learning Initiative, and supported by powerful organizations. Although there are many fields required to be completed, and it is considered by many as difficult, this implementation is considered to be very consistent by experts. This standard is today the most widely accepted specification in North America (ADLI, 2004).

The second part of this section discusses about intelligent agents, and their use in education. First, a general definition of intelligent agents is provided. According to Wooldridge and Jennings, an

Intelligent Agent (IA) is a program that has the following features (Wooldridge, Jennings, 1995):

a. Autonomy: agents work on their own, and have a high degree of control over their actions and internal state.
b. Social ability: agents react with human and other agents via an agent-communication language.
c. Reactivity: agents perceive their requests, and respond at the same time to changes that occur in their environment.
d. Pro-activeness: agents not only perform specific tasks, but they take the initiative.

Intelligent agents can be used in many domains, such as electronic commerce, manufacturing, military, education, business, psychology, and sociology. Usually, an agent is given a very small and well-defined orientation, and processing tasks in the background. In this paper, the focus is more on educational agents. The focus is to provide perspectives about how agents should be designed, in order to explore a learning repository with learning objects, and to offer tutoring, mentoring, teaching, and social interactions. According to Sampson and colleagues, an agent has the following purposes (Sampson et al., 2002):

a. Information seekers
b. Personal assistants
c. Information managers
d. Planning agents
e. Coordination agents
f. Collaborative schedulers
g. User representatives

There are many roles in which IAs can be utilized. A special subsection will describe later details about educational technological domains that incorporate intelligent agent technologies.

Educational perspectives

This section will deal with educational perspectives brought by applications using learning objects for intelligent agents. The focus of discussion will be more on educational perspectives brought by intelligent agent applications. We are interested to see what roles were implemented, what educational theories were considered, and how these were modelled.

Educational aspects modelled by intelligent agents

Learning theories and cognitive styles were discovered earlier than Learning Management Systems. From all educational models, it was important to select those which offered the possibility of being easily implemented by using software simulations. Hawryszkiewycz offered some insights about modelling and implementing flexible learning processes. In fact, there are many educational models offering diverse software modelling perspectives for agents, which became a dominant tendency of the new generation of learning systems (Hawryszkiewycz, 2007).

The education community advocates two distinct learning strategies: the objectivist model, and the constructivist model (Jonassen et al., 1995). The former model considers the world as structured and objective. Consequently, the role of the learner is to reflect reality as presented by instructor or textbooks. In an objectivist technology model, learners are guided in a step-by-step process, without considering differences for learners' backgrounds, their potentials, and their learning strategies. In contrast, the constructivist model acknowledges that a learner's reality is constructed by his or her mind. The mind is filtering the information from the world, according with its subjective perspectives. A constructivist software in learning allows students to build their learning process in a personalized path, according with their personality, abilities, and goals.

People do not learn in the same way. Learners and educational technologists were not satisfied with the objective model, that is based more on simulating rigid instructor tasks, while the individual differences of learners are not approached. For instance, Atif and colleagues opted for implementing a constructivist model for learning (Atif et al., 2003). Winn gave a special consideration to constructivism, mentioning that this approach has a major impact in changing educational systems (Winn, 2002). In fact, in recent times, constructivist frameworks have been the major trends for researchers, in their effort to build performing e-learning educational systems.

Not all educational theories can be implemented in a digital format. However, there are several educational perspectives that are already implemented:

a. Multiple Intelligence divides learning styles as dealing with words (Verbal/Linguistic), questions (Logical/Mathematical), pictures (Visual/Spatial), music (Music/Rhythmic), moving (Body/Kinaesthetic), socializing (Interpersonal), and personal insights (Intrapersonal) (Gardner, 1993).

b. The Learning Style Inventory describes learning styles on a continuum, running from concrete experience, through reflective observation, to abstract conceptualization, and finally active experimentation (Kolb, 1984).

c. Honey and Mumford Learning Styles describe the following main learning styles: theorist, activist, reflector, and pragmatist (Honey, 2001).

d. The Gregorc MindStyle and Style Delineator use the following main components: abstract-sequential, abstract-random, concrete-sequential, concrete-random (Gregorc, 2006).

e. The Learning Style Model of Felder-Silverman (Felder, Spurlin, 2005) situates the student's learning style within a four-dimensional space, with the following four independent descriptors: sensing learners vs. intuitive learners; visual learners vs. verbal learners; active learners vs. reflective learners; sequential learners vs. global learners (Sun et al., 2005b).

f. The Learning Orientation Theory uses three main types of learners: transforming, performing, and conforming. In order to be effective for learning, it was argued that there are three main requirements for agents as mentors:

   1) regulated intelligence;

   2) the existence of a persona;

   3) pedagogical control.

Dara-Abrams designed a hypermedia learning system, able to explore the cognitive Theory of Multiple Intelligences, in order to verify that this theory is suited to an online learning environment. The research was conducted in three stages: user characterization and understanding goals; development of prototype adaptive hypermedia framework and learning modules; formative evaluation of prototype. The entire study was conducted online, via a Web-based framework, developed for the purposes of the study. The evaluation from the current research indicated that further applications of the Theory of Multiple Intelligences, the Entry Point Framework, multiple representations, and the Teaching for Understanding Framework will improve the prototype, offering rich multi-intelligent adaptive hypermedia content presentations, and moving toward an implementation of "anytime, anywhere, anyone, anyhow" online learning (Dara-Abrams, 2002).
Using metadata annotation, Mustaro and Silveiro proposed an implementation, able to identify prime learning styles that learning objects offer, according with theoretical learning styles developed by Felder, Kolb or Gardner (Mustaro, Silveiro, 2006). Also, Mustaro and Silveiro implemented an instructional design framework based on the theory of cognitive learning processes developed by Gagné (Gagné et al., 1992). This implementation contained nine distinct stages:

a. Attention

b. Expectation

c. Recuperation

d. Selective perception

e. Semantic codification

f. Response

g. Reinforcement

h. Performance

i. Generalization

Roles of intelligent agents used in education

Intelligent agents technology has been applied in a variety of educational settings:

a. Information retrieval. This is often considered "the simplest" activity. In this case, agents perform searches for information, based on various criteria (Hiltz, Wellman, 1997).

b. Processing and distributing information about students.

c. Feedback collection. In this case, the system collects information about each student who participates in learning, according to their background (Huhns, Mohamed, 1999).

d. Teaching agents. This type of agent will perform directly the act of teaching. It contains scenarios to present and deliver new content and lessons to students, keeping into account details about personal profile (Selker, 1994).

e. Agents for checking assignments. This category of agents can establish assignments with different levels of difficulty, and automatically evaluate the results.

f. Agents for peer-help environments. This type of agent facilitates the interaction and the dialog with peers. It contains different scenarios to facilitate interactions (Vassileva et al., 1999).

g. Agents for providing group-support online. In this case, the scenario provides both student-teacher and student-student support interactions (Whatley et al., 1999).

h. Tutoring agents. This type of agent will emulate a peer-to-peer tutoring style (Solomos, Avouris, 1999).

i. Agents for performing interactions and collaborations in a network community. In this case, the settings have a more constructivist orientation. This type of intelligent agent is focused to produce more practical questions for the particular type of community, keeping into account different social aspects about community. In particular, cultural and social aspects are especially considered in this set of interactions (Lin, Holt, 2001).

Because the definition of the transfer of knowledge varies widely, it can be inferred that this model of applications using intelligent agents in an educational environment is only a very general approach. More details are required, in order to precisely control the creation of the contents of each educational item, to update, to modify the lessons contents, to evaluate, and to efficiently use data. In our case, intelligent agents should only partially replace the role of teachers and students. The fundamental problem with which this study is concerned is to see how the combination of these two important paradigms is implemented in one application.
A general strategy in using intelligent agents in education was designed by Jaques and colleagues. According to them, an application using intelligent agents in an educational environment should have the following categories of agents (Jaques et al., 2002):

a. Diagnostic Agent
b. Mediating Agent
c. Collaboration Agent
d. Social Agent
e. Semiotic Agent

Researchers appreciated that intelligent agents could be successfully used in empowering learners to use e-learning settings. For instance, Sampson and colleagues inferred that intelligent agent technology seems to be a promising perspective in approaching educational environments, especially influenced by Internet technologies (Sampson et al., 2002).

The challenge of building applications able to efficiently use learning objects

This section details how learning objects facilitate intelligent agents, in order to offer them opportunities to explore educational contexts. The architectural properties of learning objects are well described by Atif and colleagues. They mentioned the fact that learning objects are servers as well as clients (Atif et al., 2003). According to Sampson and colleagues, intelligent agents have four major characteristics defining their behaviour (Sampson et al., 2002):

a. Autonomy
b. Responsiveness or reactiveness
c. Pro-activeness
d. Social ability

For the entire class of applications, the main challenge for researchers was to implement these requirements through the educational contexts and rules that learning objects offered, and, at the same time, restricted the intelligent processing.

Relevant advantages of applications using learning objects

Many researchers have identified the most important characteristics that applications using LOs should possess (Berlanga, Garcia, 2004; Or-Bach, 2004; Varlamis, Apostolakis, 2006):

a. Interoperability. For the case of learning objects, interoperability requires the instructional components, developed with a set of tools and platforms, to be used in other systems and software tools. Today, interoperability is required by all systems.
b. Reusability. In the case of systems using learning objects, reusability requires that learning systems be able to (re)integrate the instructional components into a variety of contexts, applications, and systems.
c. Accessibility. In order for learning objects to be accessible, it is required that the localization and access of instructional materials be permitted, no matter their spatial situation. In the beginning, many people considered learning objects as being neutral. However, research has shown that learning objects are not neutral. They are realized by different organizations and countries, for different purposes. Consequentially, it is often necessary to verify the accessibility, the source of provenance, and the biases (Friesen, 2004).
d. Durability. Supporting new technological educational systems requires maintaining compatibility with previous versions. Learning objects have to adapt to changes in technology, without it being necessary to redesign them.
e. Standardization. Standardization, especially in the learning

objects area, requires clear specification for interoperability and processes. Standardization is extended to all aspects of the LO functionalities. However, often incomplete or unclear standards have been encountered. With all of these, in learning object technology, standardization has many advantages (Varlamis, Apostolakis, 2006).

f. Manageability. For systems using learning objects, manageability requires tracking and setting information about the learner and the educational content.

Practical problems in using learning objects

The first versions of software applications used learning objects as opaque entities, impossible to adapt to different versions of teaching styles or to learners' needs (Manouselis, Sampson, 2002). However, in the last generation of educational software projects, the tendency to particularize the product according to learning and teaching styles became general.
For instance, Atif and colleagues tried to provide an algorithm to construct individual learning routes, that are adjusted to the learner's profile as well as open implementation, able to accept integration of a large scale of learning resources (Atif et al., 2003).
Categorization is a very important aspect in a learning system. If it is only about a few courses, categorization is not difficult. However, in systems with large amounts of data, there are serious problems in maintaining consistency in categorization (Or-Bach, 2004).
Some researchers discussed social requirements that intelligent agents must have, in order to develop educational purposes (Baylor 2000; Jaques et al., 2002). For instance, Baylor considered incorporating usability and human-computer interaction properties, such as the anthropomorphic qualities, and social relationship between learner and agent (Baylor, 2000). Sun and colleagues mentioned that intelligent agents could process learning objects to facilitate personalization and adaptability (Sun et al., 2005a).
In order to offer a better feedback from students, a great number of researchers considered it essential to model, simulate, and implement the current educational theories into intelligent agent applications. Constructivism, cognitive theories, and learning styles were intensely explored, in order to improve the results

of educational agents. The following section will discuss in detail educational theories implemented for educational agents.

Areas of software applications using intelligent agents in manipulating learning objects

In relation to the way people use the metadata, learning object technologies can have: a) Tightly Coupled Metadata, and b) Loosely Coupled Metadata. Tightly coupled metadata are more associated with software engineering, while loosely coupled metadata are associated more with the Semantic Web. This is only a general approach. In fact, the use of intelligent agents in manipulating learning objects is applied in many areas of research. Sometimes, these domains do not have precise criteria to be divided. The areas of research for intelligent agents using learning objects are:

a. Instructional Systems Development (ISD) and Instructional Management Systems (IMS) (Van Rosmalen et al., 2005).

b. Learning Content Management Systems (LCMS) and Learning Management Systems (LMS) (Sampson et al., 2002).

c. Computer-Supported Collaborative Learning (CSCL) systems (Jaques et al., 2002).

d. Community-Based Learning (CBL) (Lin, Holt, 2001; Santos et al., 2004).

e. Cooperative Learning (CL) emulations (Lee, Geller, 2002).

f. Adaptive Strategies: Adaptive Text Presentation (ATP); Adaptive Multimedia Presentation (AMP); Adaptive Hypermedia Systems (AHS) and Web-Based Adapted Educational Systems (WBAES); Adaptive and Collaborative Learning (ACL) and Adaptive Learning Systems (ALS) (Brusilovsky, 1994).

g. Semantic Web (SW) (Carbonaro et al., 2005; Ishaya, 2005; Stojanovic et al., 2001).

h. Intelligent Tutoring Systems (ITS) (Solomos, Avouris, 1999).

The main question that researchers had was: what are the paramount features that make a learning system intelligent? Of special interest is the area of Intelligent Tutoring Systems (ITS). ITS theory uses knowledge about domain, student, teaching strategies, evaluations, and tutoring.

One of the most important found features was adaptability. From the new domains, one of them is Adaptive Hypermedia Systems (AHS). Adaptive Hypermedia Systems apply different forms of learners' models to adapt the content, and the links of the hypermedia environment. Brusilovsky offered a detailed solution about how, and what can be adapted. Mainly, there are two types of taxonomy: adaptive presentation, and adaptive navigation. Adaptive presentation means the adaptation of multimedia items to the specificities that the learner has. Adaptive navigation includes link hiding, link sorting, and the dynamic configuration of the map Website. For each user, AHS builds a model according with the user's goals, preferences, and knowledge. More specifically, the links from each hypermedia context are configured, so that the user can use them in a personalized way, according to his or her own individual profile. Users with different skill levels of the subjects appreciate adaptive navigation (Brusilovsky, 2001).

Intelligent agent strategies and learning objects were successfully joined together in Learning Management Systems (LMS). For the purpose of providing more flexibility in LMS, Santos and colleagues introduced the concept of intelligent LMS (iLMS), through using an intelligent agent strategy (Santos et al., 2004). Van Rosmalen and colleagues discussed the main tendencies of Instructional Management Systems (IMS). In relation with the Learning Design (LD) aspect, they mentioned that Instructional Management Systems-Learning Design (IMS-LD) should support open frameworks for the purpose of modelling competency, collaborative learning interactions, and personalization (Van Rosmalen et al., 2005). Intelligent agents in teaching are used also in Computer-Supported Collaborative Learning systems (CSCL) (Jaques et al., 2002).

One of the most general domains where intelligent agent applications were used is Instructional Systems Development (ISD). According to Van Rosmalen and colleagues, ISD has a wide scope. For them, the educational process is divided into five steps (Van Rosmalen et al., 2005):

a. Analysis
b. Design
c. Production
d. Implementation and delivery
e. Summative evaluation

Marin and Hunger developed the notion of collaboration in PASSENGER, built at the University of Duisburg-Essen, Germany, for students considered as low achievers. Collaborative learning is very important, for it provides emotional support for students who have difficulties in their courses, and helps them deal with course requirements, and support each other. In this case, the system is an intelligent agent application, designed to support collaborative learning, between two or more geographically dispersed students, through e-learning (Marin, Hunger, 2005).

Other important applications apply to the Semantic Web. The resources are processed to extract senses (not just words) from the documents. According to Stojanovic and colleagues, there are important benefits of semantics facilities:

"The new generation of the Web, the so-called Semantic Web, appears as a promising technology for implementing e-learning. The Semantic Web constitutes an environment, in which human and machine agents will communicate on a semantic basis" (Stojanovic et al., 2001, p. 1).

In this case, the classification, recommendation, and sharing phases take advantage of the word senses to classify, retrieve, and suggest documents with high semantic relevance, with respect to the student, and resource models (Stojanovic et al., 2001).

Multi-agent applications that have teaching performing tasks

Samples of software application using multi-agents in manipulating learning objects are:

a. KnowledgeTree (Brusilovsky, 2003)
b. SAIL (Slotta, Aleahmad, 2007)
c. aLFanet (Van Rosmalen et al., 2005)
d. MASPLANG (Peña et al., 2005)

e. Knowledge On Demand European Project (KOD) (Karagiannidis, Sampson, 2004)
f. Agent-Based Web Learning System (ABWLS) (Huang et al., 2004)
g. CADMOS (Retalis, Papasalouros, 2004)
h. Collaborative and Sharable Learning system (CoSL) (Lee, Geller, 2002)
i. Active Learning For adaptive internet (ALFanet) (Santos et al., 2004)

KnowledgeTree has a distributed architecture for adaptive e-learning, conceived for the reusing of educational activities. It tries to replace the monolithic structure of LMS with a community of distributed services (or servers). The system architecture has four different types of services (Brusilovsky, 2003):

a. Activity services
b. Value-adding services
c. Learning portals services
d. Student model services

An interesting design is offered in the project SAIL (2006) designed by Slotta and Aleahmad (2007). SAIL uses Java-based technology, and allows flexible ways to deploy curricula, by using a special strategy to manipulate learning objects. SAIL developed its own types of items, called curnits, pods, rims, and socks. A SAIL-based curriculum unit is called a curnit (word invented from "curriculum" and "unit" abridged). A curnit is an authored artefact. It has no information on its use. A curnit consists of a tree of pods. There is one root pod for the curnit, and it can have any number of children, as can each child descendant.
Technologically, each pod can contains multiple JavaBeans, and is the basic unit of authoring reuse. They organize bean instances, class dependencies, binary resources, and rims (see below), and they make these reusable in other curnits. Pods will be designed to support subscribed copy and prototyping; they can reference values, exported from other pods, which are set at pod reassembly time. In this case, each separate pod can be reconstituted into the

full hierarchy in the curnit. Pods are also the context of rims; these rims provide data generated during the session. Data passes through a rim into a sock. Rim is the authored artefact, but sock is where data is actually stored over the course of the offering. It is a virtual container for the use of a rim by a set of users.

To make use of a curnit, an offering is created for this. More specifically, an offering defines a temporary context of the use of a curnit. It specifies attributes, such as ownership, access restrictions, role permissions, and contexts of interaction. The offering also handles updates and modifications over the course.

Concluding comments

From the previous sections, we noticed that, based on adaptations of the e-learning model, using intelligent agents in processing learning objects should provide learning at reduced costs, increasing access to curricular knowledge, and a better accountability for learners. In this final section, we will discuss some drawbacks, and possible solutions and trends of this class of applications.

Some critics of intelligent agent implementations using learning objects

There were several discomforts and inadequacies in approaching this class of implementations. Therefore, several opinions will be considered in this section. First, there are opponents of the tendency toward standardization in education. For them, learning object technology is from the start considered to be a wrong choice (Friesen, 2004).

Secondly, in this paper, adaptability was considered to be the most important criterion in discussing intelligent agents in learning. This concept is still considered as a new domain, and stirred many controversies. Adaptation procedures are still pretty clumsy; the creation, reusability, and extension of learning objects are underperforming. At first sight, the adaptability pursued by intelligent agents seems very natural. However, as we saw in this study, it is very difficult to obtain, at this moment (Van Rosmalen et al., 2005).

Third, granularity of concepts is a serious issue, when learning objects are discussed. What is the degree of granularity, so that the object can be reused, in a variety of situations, and in a meaningful context? (Qin, Finnerman, 2002). For Or-Bach, the concept of granularity is a serious issue, when intelligent agents try to design learning activities involving high order skills (Or-Bach, 2004).

Fourth, nowadays, even the use of electronic format is still challenging for many students (Buzzetto-More et al., 2007).

Fifth, today, all intelligent agents perform far below normal teaching standards, and performing applications in teaching are still missing. One of the most pre-eminent researchers, Brusilovsky, mentioned that there are a great number of software applications for learning, but too little research was dedicated to discussing their efficiency (Brusilovsky, 2003).

Sixth, even if the concept of intelligent agent could offer a successfully potential implementation, there are researchers who are skeptical about the efficiency of intelligent agents in manipulating learning objects (Qin, Godby, 2003; Wiley, 2003). For instance, Qin and Godby mentioned that the standards for the definition of metadata do not offer enough opportunities to fully explore the content of the associated learning objects. Consequentially, it can be inferred that any intelligent agent does not have the opportunity to explore the full value of the learning content from a learning object (Qin, Godby, 2003). Also, Friesen is concerned about the lack of educational meaning, when the interactions or technical combinations with learning objects do not produce educational relevance (Friesen, 2004).

Right now, there is not any popular application of intelligent agents using learning objects, that has entered into the educational global mainstream. There are only projects and tests. Sometimes, local solutions could not be generalized. For instance, Or-Bach recommended that the creation of metadata objects should be done by students. Of course, this tendency is welcomed, as providing more hands-on experience to learners, but, obviously, without an adequate supervision, inter-operability and the coherence could be easily lost in this case (Or-Bach, 2004).

Applications should ensure Web-readability, and the capacity to export/import learning objects to different systems. In order to be able to offer improving performances for these IA applications, our educational systems should use more rigorous instructional design strategies, learning styles, and cognitive learners theories. The dialogue between educators and technicians should be improved, in order to obtain timely feedback about learning objects and intelligent agents performances. A better software simulation should be designed for social interactions. Also, the applications should perform better, in techniques of delivering learning, towards profiling extraction, by introducing a better conjunction of static and dynamic profiling mechanisms.

Further trends

As mentioned before, intelligent agents using learning objects have proved already certain advantages. Many companies and universities built new specifications that connect more specifically the two fundamental notions: Learning Objects and Intelligent Agents. For instance, some of the introduced notions are:

a. Publisher/Subscriber Communication for Adaptive Learning (Lee et al., 2003)
b. Agent-Based Online Learning (Lin, Holt, 2001)
c. PA - Pedagogical Agents (Jaques et al., 2002)
d. ABLO - Agent-Based Learning Objects (Mohammed, Mohan, 2005)
e. ILO - Intelligent Learning Objects (Silveira et al., 2004)
f. SLO - Smart Learning Objects (Mohan, Brooks, 2003)
g. Adaptive Learning Objects (Brusilovsky, 2003; Mustaro, Silveira, 2006)

Another important event is the revolution produced in the software industry by services. In recent years, the notion of service became fundamental. As the service-oriented paradigm became more mature, the learning objects paradigm started to move towards the learning services paradigm (Ishaya, 2005).
Future studies are required, in order to evaluate the efficiency of these newly designed projects in learning services. Also, in order to connect and pool together curricular information from distant computers, new trends mentioned the great potential of the strategy of building grid learning services. According to Nkambou and colleagues, grid learning services provide a large range of services and resources that fully value the effects of connectivity. These would significantly improve the support for personalized access, negotiation and dialogue with pervasive learning communities (Nkambou, 2005).

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Sintesi

La ricerca, incentrata sulle modalità di progettazione di applicativi e-learning che utilizzano agenti intelligenti per la didattica, intende rispondere a domande specifiche: come può essere digitalizzata l'informazione per far sì che sia accessibile, inter-operativa, mirata e utile nell'immagazzinare differenti aree della conoscenza? Come possono essere utilizzate al meglio le risorse digitali, in modo tale che gli studenti apprendano efficacemente? Che tipo di applicativo bisognerebbe progettare, per far sì che questo permetta di esplorare meglio le risorse digitali stesse?
A tale scopo, vengono descritte le proprietà di base degli agenti intelligenti (IA) e degli oggetti didattici (LO); evidenziate alcune prospettive educative aperte dagli applicativi IA; discusse le loro caratteristiche software; presentate aree di ricerca relative agli stessi applicativi. Conclude una prospettiva sui principali trend relativi alla classe di applicativi IA che i LO utilizzano.
Le risorse digitali sono già impiegate nei diversi gradi dell'istruzione moderna, ma la crescita di applicativi software per il trattamento delle informazioni, soprattutto nell'e-learning, è esponenziale, e l'importanza di Internet e delle risorse multimediali nell'apprendimento appare ormai indiscutibile per alcune istanze già consolidatesi: modalità anywhere-anytime, flessibilità e adattamento automatico dei materiali di corso, personalizzazione del courseware, accesso diversificato, ecc.
Per aumentare e diversificare l'accesso dei discenti alle opportunità fornite dall'e-learning, vengono analizzati i modi specifici in cui le risorse digitali sono progettate e immagazzinate, all'interno di diversi sistemi e organizzazioni, e automaticamente erogate ai discenti. Vengono descritte dettagliatamente anche alcune caratteristiche comuni a tali applicativi che, nell'erogazione di formazione,

fanno riferimento agli oggetti didattici come a sistemi software.
Nonostante molti studiosi siano scettici riguardo alla funzionalità degli IA e altri si oppongano a priori alla tendenza verso la standardizzazione nella formazione, gli agenti intelligenti che utilizzano oggetti didattici hanno comunque dimostrato di presentare vantaggi, così molte compagnie e università hanno costruito diverse nuove specificazioni che connettono, in modo più specifico, i due concetti fondamentali di Oggetti Didattici e Agenti Intelligenti.
Negli ultimi anni, un'altra nozione che ha avuto un forte impatto nell'industria del software è quella di "servizio". Con il conseguente sviluppo del prototipo service-oriented, il paradigma degli oggetti didattici ha iniziato la sua evoluzione verso un sistema di servizi didattici, ancora però in via di maturazione.
Secondo alcuni esperti, i servizi didattici di tipo grid ("distribuiti"), in particolare, fornirebbero una vasta gamma di risorse, valorizzando appieno gli effetti della connettività, con un significativo miglioramento di questioni di primaria importanza per la didattica, quali il supporto all'accesso personalizzato, la negoziazione e il dialogo con le comunità d'apprendimento, così esposte a stimoli didattici continui.
Gli applicativi IA dovrebbero garantire sia comprensibilità che qualità della rete (Web-readability), sia la capacità di esportare/importare oggetti didattici in sistemi diversi. Affinché tali applicativi possano riuscire ad offrire performance migliori, risulta necessario che i sistemi educativi utilizzino strategie più rigorose di instructional design, stili d'apprendimento e teorie di discenti cognitivi. Per ottenere un feedback utile sulle performance di oggetti didattici e agenti intelligenti, anche il dialogo tra educatori e tecnici è necessario che migliori, così come, per ciò che concerne le tecniche di erogazione di formazione rispetto all'estrazione di profili, si deve auspicare una simulazione software più funzionale per le interazioni sociali, e una migliore armonizzazione dei meccanismi di profiling, sia statici che dinamici.