UPGRADE
The European Online Magazine for the IT Professional
http://www.upgrade-cepis.org
Vol. III, No. 5, October 2002

UPGRADE is the European Online Magazine for the Information Technology Professionals, published bimonthly at <http://www.upgrade-cepis.org/>.

Publisher
UPGRADE is published on behalf of CEPIS (Council of European Professional Informatics Societies, <http://www.cepis.org/>) by NOVÁTICA <http://www.ati.es/novatica/>, journal of the Spanish CEPIS society ATI (Asociación de Técnicos de Informática <http://www.ati.es/>).
UPGRADE is also published in Spanish (full issue printed, some articles online) by NOVÁTICA, and in Italian (abstracts and some articles online) by the Italian CEPIS society ALSI <http://www.alsi.it> and the Italian IT portal Tecnoteca <http://www.tecnoteca.it/>.
UPGRADE was created in October 2000 by CEPIS and was first published by NOVÁTICA and INFORMATIK/INFORMATIQUE, bimonthly journal of SVI/FSI (Swiss Federation of Professional Informatics Societies, <http://www.svifsi.ch/>).

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ISSN 1684-5285

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Artificial Intelligence: Technology with a Future

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Joint issue with NOVÁTICA

Artificial Intelligence and Education: an Overview

Maite Urretavizcaya-Loinaz and Isabel Fernández de Castro

In this paper we present an overview of various contributions which Artificial Intelligence has made to the world of computer-aided learning. After a short introduction to the field, including a brief history of intelligent educational systems, we present some of the pedagogical trends which have influenced the development of these systems, a non-exhaustive review of intelligent educational systems, the Artificial Intelligence techniques used in them and some current lines of research.

Keywords: Computer-aided Learning, Artificial Intelligence, Intelligent Educational Systems.

1 Introduction

The terms "Artificial Intelligence" and "Education" define the distinctive nature of research activity focused on the development of educational systems based on advanced technologies [IA 2001] which take various aspects of knowledge into consideration. Nowadays the combination of new information and telecommunication technologies, and new pedagogical trends, provide the driving force behind a constant evolution; from the first computer-assisted learning instruction programs in the 50s (CAI), through intelligent tutoring systems (ITS) [Ohlsson 86] [Self 1999] to the present day when the possibilities of current hypermedia and multimedia systems [Lustosa 1993], the World Wide Web and trends in group work (collaborative systems) are fuelling the ceaseless development of distance and virtual instruction [Brusilovsky 2000] [Dillenbourg 2000] (Figure 1). We should also mention the construction environments of: ITS [Arruarte et al. 1997] [Arruarte et al. 2002] [Murray 1999], hypermedia systems [Stayanov et al. 1999] and collaborative systems [Bourdeau et al. 2002].

CAI systems are characterised, among other things, by covering complete courses, being static, being built in an *ad hoc* way and lacking good interfaces. ICAI, Intelligent CAI, systems, however, are characterised by articulating the domain, inferring the student's knowledge so as to direct and adapt the processes of instruction and learning and thereby improving Tutor-Student communication.

The Intelligent Educational Systems (IES) are tools supporting learning at all levels whose capacity for adaptation, both to learning needs and the characteristics of the user/student, qualify them as *intelligent*. The aim of IES's is to aid, collaborate with and enhance learning processes as an integrated part of the most state-of-the-art models of instruction. In other words, they should be considered as a complementary tool enabling us to increase the quality of learning, rather than as a tool to replace an entire classic training system.

In the following sections we present, firstly, different pedagogical trends and their relevance to IES environments. Then we will go on to give a vision of the Artificial Intelligence techniques used in the development of instruction and learning environments. We will later show several lines of work, including some that were presented in one of the most prestigious international conferences on this subject, I*ntelligent Tutoring Systems – June 2002, San Sebastián (Spain)-Biarritz (France)* <http://www.itsconference.com>. We will end with our conclusions.

2 Bases of Educational Technology and IES's

In the last 10 years intelligent systems developed in the field of education have undergone a great revolution, proposing systems from various pedagogical and didactic points of view.

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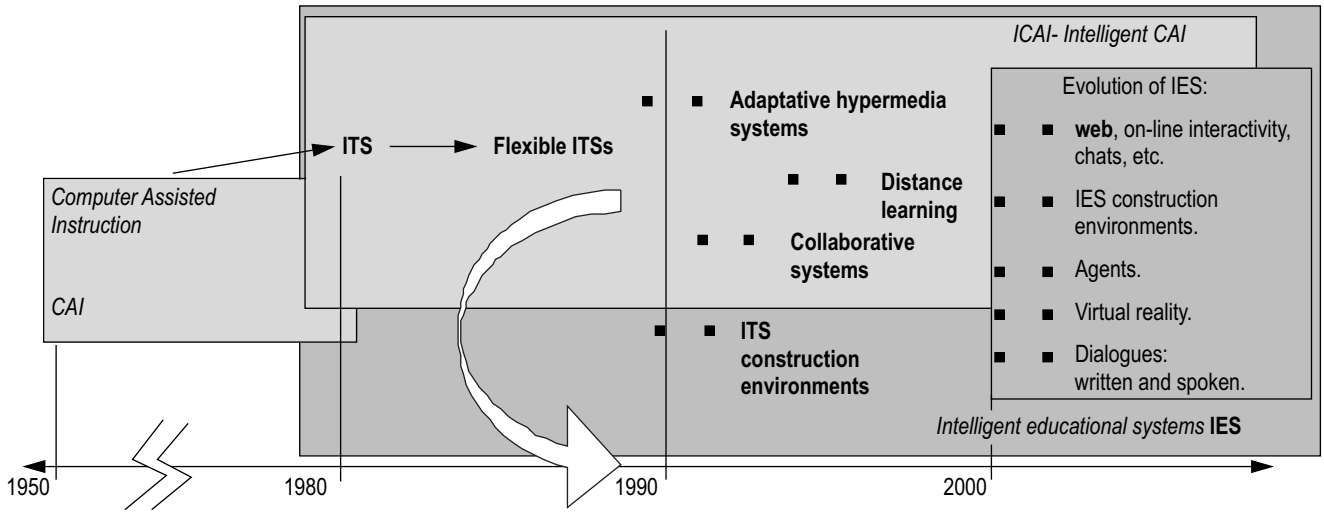

Figure 1: Evolution of Computer Assisted Instruction Systems

The *instructive* approach is the traditional educational approach in which *instruction* is understood to be *"the transmission of knowledge requiring the teacher to monitor the student constantly, especially in the problem solving processes*." ITS's have this approach [Trojahn et al. 2002]. They are a particular type of ICAI system or IES which *teach* knowledge (as transmission) in an *individualised* way, taking into account the capacity for learning and the knowledge of the student in that subject. The answer to the questions *What* is taught?, *Who* is taught? and *How* are things taught? gave rise to the classic module-based architecture (Figure 2) [Wenger 1987].

ITS's are adapted to each student by means of their diagnostic skills which examine the student's knowledge and the structuring and presentation of knowledge. They also make use of a variety of techniques to hold the user's attention and facilitate the transmission of the desired knowledge. Intelligent training systems also share this approach, although in these cases the processes are aimed more towards specific problem solving activities. The tutor guides the instruction process according to traditional practices.

Meanwhile, the *constructivist* approach [Jonassen et al. 1992] [Gil et al. 1999] establishes that *"the student should take control of his or her own learning process*." In other words, learning is seen as an *active process of knowledge construction*. This approach defines the bases of discovery and experimentation environments – a paradigm that can be immediately seen in network-based learning. Hypermedia systems [Heller 1990] [Meyer 2002] are perfectly adapted to the requirements of this approach. However, students' great mobility through hyperspace may disorient them which is why it is necessary to offer them complementary tools to give them guidance and adapt to their learning.

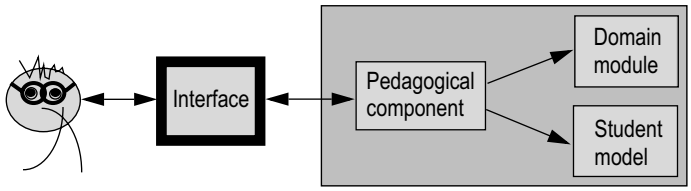

Figure 2: Classic architecture of an Intelligent Tutoring System

Both ITS's and hypermedia systems share the principle of *individualized learning*. However, these days current trends are pointing towards *group or collaborative learning* [Vigotsky 1978] [White 1999] as an alternative in order to improve quality. A network of computers becomes a basic tool for the group of students to communicate, collaborate and share the activities needed to complete a task. Systems with this collaborative approach allow the student to carry out activities such as joint problem solving, criticism of own and others' proposals, justification and explication of the solutions given and received, or access to information. A whole set of methods of pedagogical intervention have been developed to organise collaborative learning [Barros et al. 2000], competition and cooperation [Rasseneur et al. 2002], whether it be in small or large groups, face-to-face or virtual, in synchronous or asynchronous mode.

3 Computer Technology of IES's and Artificial Intelligence.

Each of the various types of learning environments described displays a series of requirements and qualities which characterise the kind of conceptualisation and formalisation suitable in each case, while requiring the use of the same number of techniques or technologies. In this section we will focus on the relation of these aspects and the most promising or most useful techniques of Artificial Intelligence in the present day, providing specific references which may complement the qualities mentioned.

Techniques coming from Artificial Intelligence concerned with symbolic knowledge modelling, such as frame or object

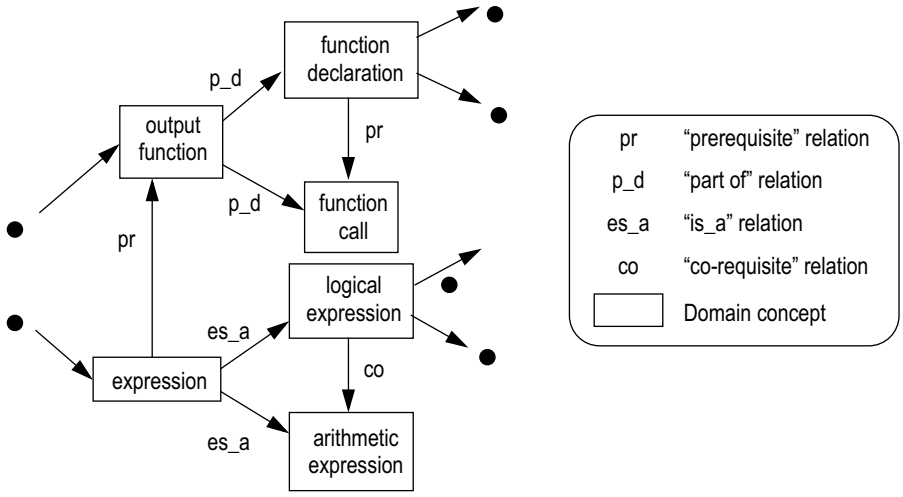

Figure 3: Domain fragment in *Tutor* [Fernández-Castro 1989].

taxonomies, have been extensively used to define knowledge of the domain or subject of the instruction of ITS's [Fernández-Castro 1989] (Figure 3). In this case, the attributes of the different nodes and their relations can represent properties described by educational theories.

Other techniques such as qualitative reasoning [Bredeweg 2002], Bayesian networks [Vanlehn et al. 2001] [Millán et al. 2000], or procedural networks have enabled the conceptual modelling of both the learning domain (especially in ITS) and the student model. Bayesian networks can also be used to model the relations between the observed actions of the student, his or her internal state and the outputs produced.

Planning techniques [Martens et al. 2002] and rule systems [Prentzas et al. 2002] (Figure 4) have allowed us to model the pedagogical behaviour of the systems in a satisfactory way. The dynamic generation of instruction plans enables both the domain and its grade of difficulty to be adapted to the user or users who interact with the instruction system.

While qualitative reasoning[1] is a technique which has been used for some years now, [Sime et al. 1992] [Vadillo et al. 1998] the use of qualitative models [Bredeweg 2002] – causal behaviour models, which together with simulation technology (outside the scope of AI) satisfactorily meet the needs of explanation, visualisation and representation of different levels of knowledge – is currently gaining a special importance.

Meanwhile, agent technology, which has revolutionised software technology in general, is having a considerable effect on how we conceptualise a classic software architecture.

Web technology's arrival on the scene and its growing acceptance by society has prompted IES to be reoriented towards the net. With this new perspective we can come across definitions such as *"ITS's are a kind of system based on Artificial Intelligence which act as wizards (which automate complicated and lengthy manual functions) in instruction-learning processes"* [Trojahn et al. 2002]. This definition can be extended to IES's.

Obviously we cannot fail to mention all those computer science techniques which, to a greater or lesser degree, form part of IES's: databases, distributed computation, a wide range of multimedia technologies, Internet, etc.

4 Some Lines of Research into IES's

IES's basically involve four different areas of knowledge related to: 1) the development of the task of instruction *per se*, 2) the corpus of knowledge or the subject you want to learn, 3) the evolution of the student's state of knowledge and 4) the component responsible for the communication between the user and the system. Also, if the system is to permit group work, it will be necessary to add a specific area for the representation of the task and group and individual behaviour.

The research carried out in this regard has been approached in various ways, from research associated with each of the areas– knowledge representation, planning of the instruction [Fernández-Castro et al. 1993] [Bretch 1990] [Elorriaga et al. 2000], natural language [Diaz de Ilarraza et al.1992], [Woolf 1992] to the development of generic architectures [McCalla et al. 1990], the study of automatic learning techniques [Dillenbourg 2000] and finally the development of design aid environments and the building of instruction systems [Murray 1999]. In the latter two cases it is even possible to model the instructor,

(-2.4) **if** teach-meth-bias is examples –exercises (1.5),
concentration-level is low (1.2),
knowledge-level is low (1.0),
percent-accessed –cunits < 0.30 (0.9),
teach-meth-bias is theory-examples-exercises (0.9)
then teaching-method is theory-examples-exercises

Figure 4: Part of a Neurorule

1. MONET <http://monet.aber.ac.uk/> is an European excellence network on Model-Based Educational Systems and Qualitative Reasoning.

with the aim of increasing the quality of the resulting ITS and even increasing the knowledge of the instructors themselves. Information could be acquired about the instructor's preferences, interests, or regular activities related to the ITS under construction; this could be used to increase the level of adaptation and aid to the instructor's needs. We should also highlight other lines of interest evidenced in [ITS 2002]: the Web and agents as a means of developing IES's, evaluation of IES systems and, finally, dialogues as a means of Tutor-Student communication, including studies on human motivation and emotions.

In the last five years, research on *dialogue* [Peinstein et al. 2002] has been taken up again with renewed vigour as a means of enabling tutor-student interaction incorporating more natural means of communication, including emotional aspects in the interaction; for example, the Reading Tutor of the LISTEN project. The maturity of the research carried out is amply demonstrated by its presence in specialised conferences on instruction, both in developed and evaluated systems. Researchers are currently studying the emotional factors arising during the learning discourse, with the aim of making educational systems more effective by stimulating the student and keeping him or her motivated. Several groups of researchers have incorporated dialogue into their instruction systems: for example CIRCSIM-tutor, PSA, AutoTutor, WHY2 system, Atlas-Andes and Ms.Lindquist Tutor. Other systems such as BEETLE and PACO are procedural task-based tutors, in which the student needs to carry out certain steps in a loose hierarchical order that he or she may or may not be aware of.

The *handling and recovery of students' errors* also deserves a special mention. There are two aspects involved: the recognition or identification of the error and diagnosis of its underlying cause, and the planning of suitable pedagogical strategies in order to recover them [Urretavizcaya 1991] [Ferrero et al. 2000] [Mitrovic 1998].

ITS's have also been applied in *industrial environments* [Frasson 1996] [Vadillo et al. 1998] [Ferrero et al. 2000] to complement their conventional training programmes. In this case multiple knowledge representation models (mental models, levels of abstraction) [Sime et al. 1992] and graphical interfaces [Rickel et al. 1999], which are often the main obstacle to the success of such systems, take on a special importance.

Group learning techniques and the integration of telecommunication technologies, chats, e-mail, debate forums, etc., form part of the line of research known as *Computer Supported Collaborative Learning* (CSCL), which allows resources, spaces and activities shared by groups of individuals to be organised and defined [Verdejo et al. 2002].

Finally, we should not fail to mention a new line of interest which aims to integrate the pedagogical capabilities of intelligent learning environments by the use of *virtual reality* (VR) in order to improve the instruction process [Eisenberg et al. 1997] [Rickel et al. 1999]. These new graphical interfaces are used with the aim of obtaining immersive systems which can emulate the real productive environment more faithfully to achieve more effective instruction. As occurs with simulation techniques, these environments are especially useful in domains in which real training is dangerous or expensive; however VR can provide a more realistic perception (visual, auditory, tactile) suitable for a wider range of situations. The users, immersed in 3D simulations of their working environments, improve their skills by carrying out real tasks. The tutors can also inhabit the virtual world with the students, collaborating with them "physically" and interacting and communicating by non-verbal means, thus widening the bandwidth of man-machine communication. It is also possible to access new information characterizing the user, such as visual attention and physical movements (e.g. position and orientation of hands). Thus VR opens up fresh possibilities for the instruction of physical tasks in new educational environments.

5 Conclusions

In this article we have presented an overview of intelligent educational systems. It was not our intention to provide either an exhaustive, extensive or in-depth study, though we have tried to supply enough bibliographical references to enable readers to go more deeply into the subjects that interest them most. As we have seen there are many lines of research open, but we would like to highlight three in particular. Firstly, the *evaluation* of existing educational systems which will enable us to improve and ensure the quality of developed systems, and therefore integrate them more effectively into centres of learning. Secondly, the new *graphical possibilities* afforded by personal computers, as a result of more sophisticated interfaces- multimedia (video, sound, animation, etc.), simulation and virtual reality techniques– together with written and spoken dialogue systems, will enhance man-machine communication. All of this will have a positive influence on the acceptance of these tools in different environments, from training centres in industrial environments to centres for special educational needs (for the visually or aurally handicapped, etc.). And finally, the *World Wide Web* and the new possibilities afforded by the Internet, which have already left their mark on the field of educational IT, will be a compulsory reference for both the evaluation and popularisation of IES's and the effective use of educational tools.

Educational IT in general, and IES's in particular are undergoing an important and exciting revolution. On the one hand, the new telecommunication technologies, the great connectivity of computers, digital lines, satellite communications, etc. and on the other, the most recent trends in cognitive psychology and the new pedagogical approaches, all have a marked effect and influence on the development and orientation of IES's.

Acknowledgements

This work has been partially funded by the Spanish Commission of Science and Technology (CICYT) through the project TIC1999-0252, and the Universidad del País Vasco - Euskal Herriko Unibertsitatea (1/UPV00141.226-T-13995/2001). We would like to give our sincere thanks to all the members of the Grupo *Galan*, the intelligent tutoring group of the Computer Science Faculty of San Sebastián, for their work and dedication.

Translated by Steve Turpin

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