Many organizations, private companies, and academic and education institutions currently devote a substantial part of their capital to employee or student training. Computer-based training/learning tools offer a cost-effective solution. Advances in information and communication technologies and, specifically, in Multimedia, Networking and Software Engineering allow the apparition of a new generation of computer-based training systems. Intelligent Tutoring Systems (ITSs) form an advanced generation of Computer-Aided Instruction (CAI) systems. Their key feature is their ability to provide a user-adapted presentation of the teaching material. ITSs have been developed and evaluated for many years in the field of artificial intelligence in education. The emergence of the World Wide Web increased the usefulness of such systems.

Internet is today the ubiquitous supporting environment for virtual and distributed learning environments. As a consequence, many institutions, both public and private, take advantage of new technologies to offer training products and services at all levels. Compared with the classical educational methods, learning over the Internet, that is, Web-based learning/training, has some advantages. First, the individual who wants to learn is not restricted by his/her geographical location or time limitation. Second, a person who can quickly grasp the subject matter need not wait for others to understand too, which is not possible in a typical classroom environment. At the same time, a person who is a little slow may take the course at his or her own pace. Third, courses developed for the Web may prove cheaper than hiring a qualified teacher each time the course is administered.

However, just putting a tutorial online does not provide education in the real sense. There is always a need for communication between the tutor and the students as well as among students. Therefore, facilities such conferencing, mailing, bulletin boards, and so forth need to be sensibly applied and integrated with the course material. The course conducted may also be a combination of classroom sessions and the Internet. More important, the Web-based learning/training systems should be very similar to human tutor. So such systems should be more intelligent through the adoption of artificial intelligence and cognitive science techniques. The Web-based intelligent e-learning
systems are interdisciplinary in nature, related closely to such fields as artificial intelligence (decision making, machine learning, planning, and scheduling), cognitive science, software engineering, Web-based information systems, and education. On the other hand, with the increasing popularity of e-learning systems, the proliferation of interoperability e-learning specifications raises the need to extend existing e-learning platforms so that they can be used efficiently in a distributed environment where material producers, service providers, and users (either learners or teachers) exchange information using standard models. The interoperability consequence of the proliferation of Web-based e-learning systems is being considered by key standardization institutions and the most relevant educational software consumers worldwide. Up to this date, proposals are available for the standardization of information models, such as educational metadata or course structures. Specifications and standards serve to build standard-driven distributed and interoperable learning systems.

This book focuses on the technologies and applications of Web-based intelligent e-learning systems and presents the latest research, development, and application results in Web-based intelligent e-learning systems. In addition to the architecture of systems, interface design, teaching and learning strategies, some major issues on the theories, key techniques, design, implementation, and applications of Web-based intelligent e-learning systems are investigated in the book. The different chapters in the book have been contributed by different authors and provide possible solutions for the different types of technological problems concerning Web-based intelligent e-learning. Each of the contributors to the book is a leading researcher in the field of Web-based intelligent e-learning who has made numerous contributions to Web-based e-learning.

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**Introduction**

This book consists of 17 chapters organized into two major sections. The first section discusses the issues of the theories, key technologies, and designs of Web-based intelligent e-learning systems in the first thirteen chapters. The next four chapters covering the development, implementation, and application issues in Web-based intelligent e-learning systems comprise the second section.

First of all, we take a look at the problems of the theories, key technologies, and designs of Web-based intelligent e-learning systems.

Inductive reasoning ability is one of most important mental abilities that give rise to human intelligence and is regarded as the best predictor for academic performance. However, most of the adaptive virtual learning environments tailor the learning material adaptively according to only learners’ domain performance thus leaving learner’s cognitive capacity, such as inductive reasoning ability, unsupported. In Chapter I, Kinshuk, Lin, and McNab present a framework of adaptive support for inductive reasoning ability in virtual learning environment based on researches in cognitive science. The authors discuss the use of the adaptive theory, Exploration Space Control, and adaptive techniques to achieve the adaptivity required in detail.
Focusing on Adaptive Educational Hypermedia (AEH) authoring, in Chapter II, Cristea and Stewart describe advances in *intra*-system automation using the LAOS framework, whereby an author is only required to create a small amount of educational material which then automatically propagates throughout the system. The authors also describe advances in *inter*-system conversions; the aim is to move away from a “create once, use once” authoring paradigm, currently in force with most AEH systems, towards a “create once, use many” paradigm. The goal is to allow authors to use their content in the AEH delivery system of their choice, irrespective of the original authoring environment. As a step along this road, the authors describe the usage of a single authoring environment (MOT) to deliver content in three independently designed Educational Hypermedia systems (AHA!, WHURLE, and SCORM-compliant Blackboard).

Automatic courseware authoring is recognized as among the most interesting research questions in intelligent Web-based education. Automatic courseware authoring is the process of automatic learning object selection and sequencing. In most intelligent learning systems that incorporate course sequencing techniques, learning object selection and sequencing is based on a set of teaching rules according to the cognitive style or learning preferences of the learners. In spite of the fact that most of these rules are generic (i.e., domain independent), there are no well-defined and commonly accepted rules on how the learning objects should be selected and how they should be sequenced to make “instructional sense.” Moreover, in order to design adaptive learning systems, a huge set of rules is required, since dependencies between educational characteristics of learning objects and learners are rather complex. Karampiperis and Sampson address the learning object selection and sequencing problem in intelligent learning systems in Chapter III, proposing a methodology that—instead of forcing an instructional designer to manually define the set of selection and sequencing rules—produces a decision model that mimics the way the designer decides, based on the observation of the designer’s reaction over a small-scale learning object selection case.

Augar, Raitman, Lanham, and Zhou introduce the concept of virtual learning communities in Chapter IV and discuss and further enhance the theory and definitions presented in related literature. A model comprising four criteria essential to virtual learning communities is presented and discussed in detail. Theory and case studies relating to the impact of virtual learning communities on distance education and students from diverse cultural groups are also examined. In addition, the authors investigate the enabling technologies and facilitation that is required to build virtual learning communities. Other case studies are used to illustrate the process of building virtual learning communities. Emerging technologies such as wikis and video lectures are also analyzed to determine the effects they have on building and sustaining effective virtual learning communities.

Learning is more than knowledge acquisition; it often involves the active participation of the learner in a variety of knowledge- and skills-based learning and training activities. Interactive multimedia technology can support the variety of interaction channels and languages required to facilitate interactive learning and teaching. A conceptual architecture for interactive educational multimedia can support the development of such multimedia systems. Such an architecture needs to embed multimedia technology into a coherent educational context. Pahl investigates the development of interactive educational multimedia as a platform to implement activity-based learning and training.
through a conceptual architecture in Chapter V. This architecture is open to further extensions, integration with other frameworks and standards, and adaptations to particular needs.

Jaques and Viccari put their focus on the current state of the art of the e-learning systems that consider the student’s affect in Chapter VI. The authors present the perspectives adopted by the researchers for the solution of the problems (for example, which kind of tools we might use to recognize users’ emotions) and also some better-known works in order to exemplify. It also describes the necessary background to understand these studies that involves some concepts on Artificial Intelligence, Computer in Education, and Human-Computer Interaction research fields, as well as a brief introduction on the main theories about emotion. The authors also present challenges and the main difficulties of the research in affectivity in e-learning systems and ideas on some new work on the matter.

In Chapter VII, Carbonaro introduces how to use a Web-based hybrid recommender system developed with a collaborative bookmark management system approach. The system combines content analysis and the development of virtual clusters of students and of educational sources. It provides facilitation in the use of huge amount of digital information stored in a distributed learning environment on the basis of the student’s personal requirements and interests. By adopting a hybrid approach, the system is able to effectively filter relevant resources from a wide heterogeneous environment like the Web, taking advantage of the common interests of the users and also maintaining the benefits provided by content analysis.

MetaLinks is a domain-independent authoring tool and Web server for adaptive textbooks (“hyperbooks”) that supports active reading. Murray shows how cognitive and educational research and theory from the areas of text comprehension and active reading strategies can be applied to hyperbooks in Chapter VIII. Adaptivity and other MetaLinks features allow us to create a single hyperbook that serves multiple purposes. A MetaLinks hyperbook can serve as textbook and reference book, can be equally appropriate for novice and advanced readers, and can be coherently read from a number of thematic perspectives. “Active reading/learning” refers to a set of high-level reading, searching, problem-solving, and metacognitive skills. The author describes the MetaLinks system and how its features support a number of behavioral, cognitive, and metacognitive active reading skills.

Hatzilygeroudis and Prentzas deal with knowledge representation in intelligent educational systems (IESs) in Chapter IX. The authors make an effort to define requirements for knowledge representation (KR) in an IES. The requirements concern all stages of an IES’s life cycle (construction, operation, and maintenance), all types of users (experts, engineers, and learners) and all its modules (domain knowledge, user model, and pedagogical model). The authors also briefly present and compare various KR schemes as far as the specified KR requirements are concerned. It appears that various hybrid approaches to knowledge representation can satisfy the requirements in a greater degree than that of single representations. Another finding is that there is not a hybrid scheme that can satisfy the requirements of all the modules of an IES. So, multiple representations or a multi-paradigm representation environment could provide a solution to requirements satisfaction.
Combining methods of Artificial Intelligence and Cognitive Science led to the development of ITSs more than 30 years ago. In contrast to the common agreement about the ITSs’ architecture, components of ITSs are rarely reusable. Reusability in ITSs is intimately connected with the application domain, that is, with the contents that should be learned and with the teaching and learning strategy. An example of a learning strategy is case-based learning, where the adaptation of the learning material to the learner plays a major role. Adaptation should take place automatically at run-time, and thus should be part of the ITS’s functionality. To support the development of ITS with reusable components and the communication about and the evaluation of similar ITS, a formal approach is chosen. This approach is called the tutoring process model. In Chapter X, Martens describes a formal, adaptive tutoring process model for case-based ITSs.

Current standardized e-learning systems are centred on the concept of learning object. Unfortunately, specifications and standards in the field do not provide details about the use of well-known knowledge representations for the sake of automating some processes, like selection and composition of learning objects or adaptation to the user or platform. Precise usage specifications for ontologies in e-learning would foster automation in learning systems, but this requires concrete, machine-oriented interpretations for metadata elements. In Chapter XI, Sánchez-Alonso, Sicilia, and García put their focus on ontologies as shared knowledge representations that can be used to obtain enhanced learning object metadata records in order to enable automated or semi-automated consistent processes inside Learning Management Systems. In particular, the authors present two efforts towards enhancing automation: a contractual approach based on pre- and post-conditions, and the so-called process conformance profiles.

The fast development of technologies requires specialized and complex skills that need to be renewed frequently. Thus, the role of continuing education and lifelong learning is becoming still more important. E-learning adapts well for continued education as it can be done in parallel to other work. This in turn sets new requirements for universities: they have to build e-learning infrastructures, and course material has to be in digital form. Moreover, the e-learning systems should be designed in a way that they provide easy access to courses and course material. A cornerstone of easy access is the metadata attached to courses and other relevant elements. However, the mere metadata itself is not very useful without the ontology that gives the semantics for the metadata. Puustjärvi gives an overview of the role of metadata and ontologies in e-learning systems in Chapter XII. The author also considers the standards of educational metadata and the utilization of metadata and ontologies in three e-learning systems.

As e-Learning gets more widespread, its definition is becoming more distinctive, implying the use of the Web for learning. The Web’s original functionality was to provide access to materials located in servers. This has been the core strategy for e-Learning. However, the Web is becoming more versatile. The new interactive Web functionalities are organized in services offered to users. The content-based Learning Management Systems are evolving into more interactive systems providing agent-like learning services rather than only learning content. By designing an interactive environment with a learning objective, we can develop an effective e-Learning appliance: the application
of strategic Web functionalities on a technologically enhanced learning environment. Ortega and Sánchez-Villalón present AWLA in Chapter XIII. Designed under the constructivist perspective, AWLA is an organized set of interactive Web-based utilities that—when applied in a technologically enhanced learning environment—allow learners to develop their writing skill in language learning and fulfill writing activities in any other discipline, both individually and in collaboration.

In the second section, we see some development, implementation, and application issues of Web-based intelligent e-learning systems. The North Dakota State University (NDSU) World Wide Web Instructional Committee (WWWIC) is an inter-disciplinary research team that since the 1990s has developed multi-user, interactive virtual environments (IVEs) to teach the structure and process of various branches of science. The most developed of these include the “Geology Explorer” and the “Virtual Cell,” (VCell). In Chapter XIV, Daniels et al. describe the key features the Virtual Cell and the Geology Explorer, the underlying philosophy and educational theory guiding their development, and results of large controlled experiments that investigate their effectiveness on student learning. Additionally, ongoing projects and experiments of the team relevant to the development and dissemination of these software programs are explored.

In Chapter XV, Bouras, Nani, Panagopoulos, and Tsiatsos present the design and implementation of an integrated platform for Educational Virtual Environments. This platform aims to support an educational community, synchronous online courses in multi-user three-dimensional (3D) environments, and the creation and access of asynchronous courses through a learning content management system. In order to offer synchronous courses, the authors have implemented a system called EVE-II, which supports stable event sharing for multi-user 3D places, easy creation of multi-user 3D places, H.323-based voice-over IP services fully integrated in a 3D space and as many concurrent 3D multi-user spaces.

Woolf and Stern describe Web-based instructional tutors that support active and engaging learning in Chapter XVI. Towards that end, a theoretical foundation for designing such tutors is proposed and two Web-based tutors described. The tutors reason about a student’s knowledge and their own teaching strategies while taking advantage of the possibilities of the Web by being open to other resources (Web sites) and other people (online communities). One tutor, Rashi, provides problem-based activities and tracks a student’s critical thinking in biology and geology, and the second, iMANIC, uses hypermedia to customize online lectures for individual students based on learning need. This work provides promising data points for the development of authentic and effective learning that can take advantage of the possibilities of the Web, without being rooted in extensions of what already exists in the classroom, such as lectures or bulletin boards.

Kordaki presents the concept of Special Purpose E-Learning Environments (SPELEs) in Chapter XVII. The main aim of these environments is to meet the learners’ individual learning differences related to a specific learning subject. The author presents an architecture of the design of SPELEs. The background of this design, which is based on interpretations of modern constructivist and social views of learning in the Internet context, is also presented. Based on this architecture, a specific SPELE, designed to the
learning of concepts related to Files and Peripheral Storage Devices (F.P.S.D.), is demonstrated and its pilot evaluation study with real students is reported. The analysis of the data verifies the theoretical design of SPELEs, which consists of five parts: (a) organization of the content of a specific learning subject, (b) learning activities, (c) learner activity space, (d) learner assessment, and (e) learner communication. The analysis of the data also gives evidence for future improvements of the specific SPELE mentioned above.