Advanced architectures for adaptive hypermedia in interactive learning environments

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Abstract: Lately, computer-assisted learning has become one of the most dynamic fields of multi-disciplinary research. The major issues studied in this field have been the development of systems focusing on acquiring skills; while in the beginning, such systems were not quite adequate to the learner’s profile and did not provide guidance in decision making throughout the learning cycle, they are now becoming increasingly intelligent, with more and more powerful pedagogical capacities. The emergence of new information and communication technologies (NICT) and especially of artificial intelligence technologies has revolutionized thinking in this respect for several reasons: firstly, ICT can be used to disseminate knowledge on a wide scale; secondly, courses can be selected tacking into account the behavior of the learner, her expectations and her preferences. Therefore, hypermedia systems are now new ways of reading and accessing information. The courses are no longer progressive accumulation on a linear, predetermined and unique scale of knowledge, entirely standardized for all the prospective users; instead they can now be adapted to specific profiles of potential learners. In the literature of the field there are three categories of such systems: classical hypermedia, adaptive hypermedia and dynamic adaptive hypermedia. Our study aims to present the conceptual model of a dynamic adaptive hypermedia system, which has been developed within the research project called „Studies on advanced modeling of tutorial systems in virtual educational environments“.

Key-Words: Information and communication technology, Dynamic adaptative hypermedia, Internet, Computer-assisted learning

1 Introduction

The hypermedia systems offer a new direction of research in computer-assisted learning. They have a significant impact upon the use of information and communication technologies in education (ICTE) due to the fact that they take into account, among others, “adaptation” and “adaptability” of the various actors in the computerized environments of human learning and at the same time aim to mitigate the feeling of disorientation and cognitive overload often found in the learner that uses intelligent or interactive means of learning, providing the necessary support for motivation and school progress.

2 The theoretical underpinnings of computer-assisted learning

Use of computers in education has almost always been inspired by the pedagogical models that occur in several schools of thinking, which basically differ from each other in the degree of freedom granted to the learners in the process of learning. First, we should mention behaviorism, initiated by John B. Watson, and where Skinner was one of the earliest representatives of computer-assisted learning. He held it that a person may learn any concept as long as the technique of programmed instruction based on the division of a concept into so-called frames is used. Frames are simpler elements, which are presented to the learner in a succession. The learner assimilates them in her own pace through a system of questions and answers. Next, the constructivist movement, established by J. Piaget, gives the learner more freedom and supports the idea that learning occurs as a result of interactions between the learner and the computer. Finally, cognitivism – which was developed once with artificial intelligence, put forward by Bruner [3] as a response to behaviorism – focuses on studying the individual’s state of mind, and is subdivided into two schools: symbolism and connectionism. From the symbolist standpoint, the brain works as a computer, therefore studying computer programs operating with symbolic will lead to a better understanding of the brain. In this case, information is modeled as a filtering of stimuli, followed by mental formalization and representation, then by calculus (deduction, induction, comparison, etc.). This model has its limits, because the use of symbols is only part of the brain’s activity. From the perspective of
connectionism, the brain does not work after a model of logical serial calculus, but rather after a model of network calculus. In fact, the two models are complementary: symbolism looks upon learning at the macro level, while connectionism at the micro level.

Consequently, the psycho-pedagogical and psycho-social strategies regarding the use of ICTE are based on both the paradigms of behaviorism [25], [26], [16], constructivism [18]; [17]; [11]; [10] and cognitivism [3], and on the paradigms of applying information and communication technologies in education.

3 The evolution of computer-assisted learning systems

3.1. Intelligent tutorial systems

There are two fields of research that look into the issue of computer-assisted learning, namely intelligent learning and interactive learning. The first one relies on the systems’ intelligent behavior, while the second focuses on learning by interaction. The intelligent tutorial systems (ITS) are perfectly framed by the field of computer-assisted intelligent learning. They appeared in the 1970s and 1980s, when due to progress in problem-solving and representation of knowledge, they attempted to produce systems that simulate the human teaching agent, systems that have the capacity to resolve (hence the adjective “intelligent”) and guide the learner when she makes an error (hence “tutorial”). Generally defined as a system of learning with a teaching objective to transmit knowledge, but especially to develop competences, an ITS includes four components: a domain model which allows “reasoning”, i.e. answering the student questions and supervising him or her to help correct errors; a learner model which allows it to establish the level of her knowledge at any time; a pedagogical module, which monitors the learner’s behavior and her model, can make choices along the school career; and an interface module, which transmits and decodes the information of the system for the user and vice versa [23]. The field literature emphasizes the fact that in order for an ITS to be “intelligent”, it must integrate the four components mentioned above, and in order to adapt to the user it is enough to have two components: the domain model and the learner model. In essence, the domain model serves the structuring of knowledge, and the learner model allows the adaptation of the content and of the hypertext connections that will be presented to the user in the form of hypermedia pages.

Interconnection between the domain model which structures knowledge and the hypertext connections that will be presented to the user may be done in three ways: page indexation, fragmented indexation and direct relation [4] [2] [7] [22].

Chronologically speaking, the SCHOLAR system is thought of as the parent of ITS. The systems developed later (GUIDON I [6] GUIDON II [27] or APLUXIS [20]) attempted to improve successively each component of the ITS architecture. In the early 1990s, there were created the ITSs that took over the old ITSs’ capacity to “reason” and added interaction in learning (e.g., DEMAUTO [19]).

In addition to the studies to make the computer-assisted systems of learning more and more “intelligent”, lately most researchers have shifted their focus on the production of multimedia courses online; the production observes a series of standards that are strictly necessary for such an approach. To this end, systems of learning focusing on improving the learners’ competences were developed and used; however, the courses distributed through the Internet most often concentrate on transmission of knowledge in the first place. Some exceptions are some ITSs that open up to the Web, such as those written in SAFARI [8]. ITS that keep in mind that the Web – one of the Internet services – is the cornerstone of ICTE in which acquisition of knowledge relies basically on the simple principle of the hypertext. The hypertext can be defined structurally [1] as a set made up of nodes and links, functionally [24] as a computerized procedure through which an entity (regularly a minimal one, such as a word, an image, a pictogram) is associated another entity (often more elaborate, such as a paragraph, an image, a page), and semantically [14] as an entity made up of other two entities, namely a set of documents and a set of knowledge elements.

The current development of computer-assisted learning, which claims to be intelligent and interactive, has benefited from progress in multimedia resources of computers both in terms of material (sound chip, MPG video decomposition chip, 2D and 3D video maps, etc.), and in terms of programming packages (various coding, decomposition algorithms, etc). In addition, due to the global Internet, computers can be easily connected, which means a constant evolution of the computerized educational program packages (or educational software), which thus become better, more attractive and easier to locate. The advantages listed above can benefit all types of education: in the traditional education system it can help learners with
difficulties prone to classical school failure, but also those with other issues (e.g. it is important for learners who are hospitalized or bedridden to be able to take courses); distance learning for increased quality and avoidance of the traditional courses through “correspondence”, as well as for long life learning, for instance, to reduce the training-related costs.

3.2. Hypermedia systems

Towards the end of the 1990s, the development of new technologies, as well as the increased capacities of the microcomputers allowed the development of learning systems in which the buzzword is “multimedia”. The fusion of “hypertext” and “multimedia” leads to the emergence of the concept of “hypermedia”, which underpins several instruction environments as well as self-instruction. There are three such categories of systems: first there were the so-called classical hypermedia systems, then the adaptive hypermedia systems, and finally the dynamic adaptive hypermedia systems [5] [21] [12].

3.2.1. Classical hypermedia systems

Unlike the hypertext systems made of nodes and links in which the nodes or the hypertext pages are made up of information in the form of text, and the links between the nodes are ensured by one or several highlighted words, which indicate to the user that a new page can be visualized. Hypermedia differs from hypertext through the content of the nodes: in addition to text, these contain diverse other media, such as fixed and animated images, video, etc. The advantages of using classical hypermedia systems are ensured by the multimedia and hypertext components in their structure, which can contribute to the improved quality of learning. But these two advantages can rapidly turn into disadvantages because they confuse the user and cause cognitive overload. Confusion results from the learner’s freedom to move in the system from one node to the next, and cognitive overload is caused by the flood of information which risk “overflowing” the system.

3.2.2. Adaptive hypermedia systems

The adaptive hypermedia systems try to fix the disadvantages of the classical ones through adapting the presentation of teaching material and assisting the learner in moving inside hyperspace. In such a system, both the content of the pages and the links between them can be modified (using different techniques such as direct guidance, ranking, hiding, or annotating the links). The architecture of adaptive hypermedia systems is based on two models: the domain model and the learner model. In general, these systems are defined by the relation they maintain between the domain model and the media used for presenting the information to the learner. As compared to the classical hypermedia systems, these are a progress that should not be neglected. The advantages of the adaptive hypermedia systems are conferred by the different techniques made available to the learner for guidance – without taking away the freedom to navigate, which is intrinsic to hypermedia – and for a better structuring of knowledge along the learning process. However, there are some disadvantages involved. One of them is that they emphasize the adjustment of links to guide the learner and not the adjustment of content. Indeed, a great many adaptive hypermedia systems originate from the already existing classical hypermedia systems to which researchers have added some tools for adjustment. It is easier to hide or annotate some links and much more difficult to replace a page or even change the structure of a page. Another shortcoming is the lack of uniformity in the structure of the courses and the opportunities for immediate application of knowledge.

3.2.3. Dynamic adaptive hypermedia systems

Dynamic adaptive hypermedia systems are characterized by the fact that they provide a virtual hypermedia. In this case, the system is no longer made up of predefined pages and links, but these are constructed dynamically. Such a system of dynamically constructed pages and links has at least two advantages. Firstly, the addition of a new support can be done immediately, and secondly, the hypermedia producers need only define the general architecture of the system, and assign, retrieve or create documents that will be used to present each concept.

4 Project presentation. A conceptual model of tutorial systems used in e-Learning environments

4.1. Conceptual framework and objectives

Our research project - “Studies on advanced modeling of tutorial systems in virtual educational environments” - has as a point of departure the following observations: research on hypermedia learning systems has developed from classical hypermedia usage to dynamic adaptive hypermedia; currently hypermedia based on dynamic adaptation are relatively rare; many of them rather draw on hypertext than media or hypermedia components and use the Internet in order to deliver information
very rarely. Although there is a large tendency to use this type of systems nowadays, further developments need to be done on theoretical and applicative grounds.

For a dynamic adaptive hypermedia system able to generate and distribute courses with real multimedia features through the Internet, available anywhere regardless of the geographical position of the learner, the literature puts forward a conceptual model with the following components: a domain model which allows saving the teachers pedagogical knowledge; a learner model divided in two sub-models: the behavioral and the epistemic sub-models; a multimedia database (elementary components) which allows the description of the teaching materials that will introduce the notions of the domain and a course generator for the dynamic construction of the hypermedia pages. Together, the four components lead to the conceptual model of a dynamic adaptive hypermedia system.

As a consequence, given the theoretical context, the above mentioned research project advances some ideas for a conceptual model of an adaptive dynamic hypermedia system that would consider adaptation in both links through and content of pages, using multimedia data in order to present courses and the Internet in order to deliver them.

The main objective of the research project is to develop conceptual models and specific architectures for the long distance learning applications based on intelligent hypermedia systems. Due to such a system, the student surpasses linearity of documents and gains access to dynamic information, which is nevertheless still to be adapted to her needs, in our opinion. Adaptability needs of the learner lead us to think of such a medium on different dimensions: pedagogical, social and informational-technological.

Also, our research project has several specific objectives: 1) development of a data and services structuring model, suited for an adaptive dynamic hypermedia system used in delivering courses that reprocess pedagogical items; 2) support for intelligent, student oriented and pedagogical outputs aimed resource management; 3) identification of new solutions to increase quality of system adaptability; 4) ensuring of global system adaptability; 5) development of intuitive working tools.

4.2. Innovation, trends and perspectives

Although based on the global architecture of adaptive hypermedia systems and besides the fact that it increases the quality of the domain model and the learner model as well in order to insure adaptation in both formal and content aspects, the system we advance in this paper is different from other hypermedia learning systems for several reasons: it uses filters in order to select media resources useful in concept presentation; it unifies course structure in order to decrease the feeling of disorientation while learning; it takes into account both the level of knowledge and the distinct preferences of each and every learner; it provides a specific structure that allows putting together knowledge of several teachers in a given area and also it constantly uses the latest technology in hybrid distributed intelligent systems (evolutionary computing, swarm intelligence etc.) and object-oriented data bases.

Information and communication technology used in education provides several opportunities. The first and most important is the pedagogical opportunity, since it is the very purpose of education. Despite strong historical connections between education and ICT, education proves to be reluctant to mediated means of learning and information delivery. Nevertheless, some authors believe that education integrates ICT better nowadays, due to social pressure. Secondly, there is the social opportunity of ICTE. In their analysis of knowledge in information technology-based societies, some researchers claim that in the context of contemporary postindustrial era and postmodern culture universities and high education institutions are expected to produce skills and to provide the labor market with well prepared players which should be capable of playing their role in given critical work positions. We should then consider the economical opportunity, since ICTE requires often important investments. Polemics around the access to digital contents available on the Web do not elude education, and that is why the juridical opportunity is also of great importance in ICTE. One of the main issues is whether the content one teacher inserts or directly creates on a long distance access platform should or should not be freely accessible and also whether this kind of work provides the teacher with a copyright. Web application cannot be explained without using the concept of digitalization and its implications. It follows from here the technological opportunity in ICTE. Indeed, differences in produced content result from fundamental transformations of tactile substance into a string of numbers, of physical entity into digital code. As a subsequent outcome, IT innovation in hypermedia-based platforms facilitates mobility, free-generation of contents, immediacy,
interactivity and delocalization.

Hypermedia systems are a new means of information delivery. Nevertheless, the use of adaptive dynamic hypermedia systems in education raises a few questions, such as: What are the artificial intelligence procedures these systems use? What sort of knowledge should such a system integrate? How are dynamic pages produced in hypermedia systems? How should this kind of system be developed in order to make it accessible using a common Web navigator? How should we characterize the learning objects?

Collaboration within multidisciplinary teams is very important in order to succeed in such a research endeavor. We name here only three of the areas involved: firstly, there is the education and learning field, and computer mediated technologies area also (pedagogical learning theories, intelligent computer-assisted learning, artificial intelligence, interactive media for human learning, long distance learning, cooperative computer-assisted learning etc); secondly, there is the Web-based information systems, with all the technology around them (Internet, Intranet, Web, Client-server model, Web Server, Navigator, HTML, Xml, Java, Applet, CGI etc) and thirdly, the field of computer-assisted cooperative activity, or, more precisely, the area of the cooperative editing of structured documents applications.

Our research project is interdisciplinary also from a theoretical point of view. We use theories from the social and cultural perspectives, such as Activity Theory, initiated by Leontiev [1977] and further developed by Engelström [8] and Social Networks Analysis, also known as the theory of structural interactionism, together with informational paradigms (such as analysis, production, specification and development of adaptive hypermedia systems) and elements of Distributed Artificial Intelligence (such as allocation process, intersystem communication, human activity and intelligent entities modeling).

5 Conclusion

Alongside ITS and the intelligent and interactive learning environments, the hypermedia systems nowadays become an essential component in computer-assisted learning. Their major advantage, namely the non-linear progress of the learner, may however become a disadvantage: the learner may quickly get lost in hyperspace, i.e. in the graph that makes up the pages and connections of the system. Trying to fix this shortcoming, and to guide the learner in her school progress depending on her knowledge in the field to be explored, recent studies have focused primarily on dynamic adaptive hypermedia systems, which create pages and links in hyperspace a dynamic manner, taking into account the user’s features and objectives, simplifying the space to be explored and reducing to a minimum the adapted part offered to the user.

The dynamic adaptive hypermedia systems are a real challenge for researchers in the field of computer-assisted instruction. They provide a new method to transmit information, and nowadays, their use on education cannot be overlooked. Although some studies have tried and still try to minimize the cognitive impact of hypermedia – an increasingly difficult task given the emergence of dynamic adaptive hypermedia systems – their prevailing position in information and communication technologies makes them unavoidable. The dynamic adaptive hypermedia systems are definitely a part of the elaborate and critical attempts of improving hypermedia systems.

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