Conceptual models and advanced architectures for adaptive hypermedia systems in education

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Abstract: 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 (ICT) 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 destined to structuring courses based on the concept of reusing didactic items have started to be developed. In the literature of the field there are three categories of such systems: classical hypermedia, adaptive hypermedia and dynamic adaptive hypermedia.

Key-Words: Information and communication technology, Dynamic adaptive hypermedia, Computer-assisted learning, Internet, Learning systems

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. At the same time, the hypermedia systems 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. An *adaptable* system is a system that can be modified at any time by the explicit request of the user. With this type of system, user-defined preferences are stored by the system within a pattern which can be modified again only following a new request explicitly formulated by the user. An *adaptive* system is a system that modifies itself automatically as a function of the needs (requests) and preferences of the user. User behaviour tracking mechanisms consider environment, psychical estate and knowledge of the user in evaluating her needs. The system updates the pattern after observing the actions and reactions of the user. With adaptable systems, the programmer makes the update. Users (or some of the users) do not interfere, but they are previously identified by their requests. The system can adjust the way it operates during execution only on the basis of a sample of predefined behaviour patterns, which can be more or less adequate to the specific situation. With adaptive systems, the requests and preferences of the user are also considered, the difference between adaptation and adaptability being that with the latter necessary adjustments and preferences updates are no longer the concern of the user, instead they are deduced following the actions of the user. With this type of systems, the user is no longer forced to learn how to adjust the interface or to memorize different specification languages in order to operate the necessary changes. This way she can focus on how the software works and on completing the tasks, relying upon the system working properly understanding her needs and objectives and memorizing those requests also. Adaptability has both advantages and disadvantages as it works independently from the user. Major disadvantages are disorientation risk for the reader, if she lacks ability to build the meaning of the whole starting from the parts or the risk of cognitive overload, when there are too many possibilities offered. This happens when one of the basic principles in software ergonomics is ignored: within a well defined system the same actions always should lead to the same responses.

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 elementary units or 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. Computer-assisted learning turned behaviourism into either a positive model (cutting the learning content in simpler learning units, instant content learning, personalizing learning rhythm and active learner participation) or a negative one (learning based on success and not on intellectual mechanisms) [30]. Even though behaviourism stands at the origin of introducing informatics in school, its core model – purely behaviourist and rejecting mental representations – lead to a simplistic stimulus-response learning theory which is too weak to be sustainable. Next, *the constructivist movement*, established by J. Piaget [28], gives the learner more freedom and supports the idea that learning occurs as a result of interactions between the learner and the dynamic environmental factors. Constructivism sees knowledge as a result of active building, based on experience. This theory leads to various forms of pedagogy, such as non-directive pedagogy (freedom of the student) or objectives-based pedagogy (practice versus abstract knowledge). Finally, *cognitivism* – which was developed once with artificial intelligence, put forward by Bruner [5] as a response to behiorism – focuses on studying the individual's state of mind, and is subdivided into two theoretical perspectives: *symbolism* and *connectionism*. From the symbolic standpoint, the brain works as a computer, therefore studying computer programs operating with symbols 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* [35], [37], [27], *constructivism* [28]; [20]; [19]; [18] and *cognitivism* [5], 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 [32]. 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 hypermedia pages presented to the user may be done in three ways: *page indexation*, *fragmented indexation* and *direct relation* [6] [4] [15] [31].

Chronologically speaking, the SCHOLAR system is thought of as the parent of ITS. The systems developed later (GUIDON I [11] GUIDON II [38] or APLUXIS [26]) 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 [24]).

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 [17], 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* [2] as a set made up of nodes and links, *functionally* [33] as a computerized procedure through which an entity (regularly a minimal one, such as a word, a part of an image, a pictogram) is associated another entity (often more elaborate, such as a paragraph, an image, a page), and *semantically* [25] 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 decompression chip, 2D and 3D video maps, etc.), and in terms of programming packages (various coding, decompression 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 in educational environments

Ever since they first appeared, hypermedia systems seem to be a new tool for knowledge deliverance because of their structure and characteristics and this make them useful in education. 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 [9] [29] [21].

The development of hypermedia systems was preceded by the creation of other specific instruments, such as: 1) instruments for building multimedia documents that integrated and synchronized different types of media (sound, image, etc.) within the same entity; 2) instruments for managing these documents which were used to correctly index and store documents so that they could be found and used again afterwards; 3) instruments for linking documents in order to build coherent courses. Flash package produced by Macromedia is an example of an instrument in the first category, that of the instruments used in order to build didactic items. Didactic items are understood here as multimedia or non-multimedia items which have an inner pedagogical quality, meaning that they can be used in order to transmit knowledge.

ARIADNE systems (*Alliance of Remote Instructional Authoring and Distribution Network for Europe*), CDE (*Course Designer Environment*), OLA (*Online Learning Application*) and SEMUSDI provide instruments for managing didactic items, while *Archymedia*, *Learning Space*, MEDIT (*Multimedia Environment for Distributed Interactive Teaching*) and *WebCT* are representative for the last category of instruments used to develop hypermedia systems.

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 presentations, 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, while 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 of adaptive hypermedia systems is the lack of uniformity in the structure of the courses and the opportunities for immediate application of knowledge. Adaptive hypermedia systems used in education are most popular. INTERBOOK [7], TANGOW [10], Smex Web [1], AHA [12], ISIS-Tutor [8] and DCG [36] are some examples of such systems.

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. METADYNE [13], TANGOW [10], CAMELEON [22] and HYPERGAP [34] are some examples of dynamic adaptive hypermedia systems.

3.2.4 Utilization of ICT systems in education

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.

4 The conceptual model of dynamic adaptive hypermedia systems for education

4.1. Criteria and objectives for a conceptual model of adaptive hypermedia in education

Research on hypermedia learning systems has developed from classical hypermedia usage to dynamic adaptive hypermedia. Currently hypermedia based on dynamic adaptation are still 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. Due to them, there are now new possibilities to read, to access information. Contents are no longer seen as progressive accumulation on a gradual scale of knowledge, invariable, the same for each and every one. Instead, the contents are adapted to potential user profiles.

To design 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, some recommendations are required. Taking into account the inner characteristics of dynamic adaptive hypermedia systems, here are some requests of such a system: a) it should provide uniform courses, with real multimedia characteristics; b) it should consider both level of knowledge and objectives of the learner; c) it should provide a group of teachers with a data structure that would allow them to present and put together their knowledge in order to improve the system adaptation. 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.

Additional to the previously mentioned criteria, a dynamic adaptive hypermedia system has to be oriented to the following objectives.

1. A dynamic adaptive hypermedia system has to develop a data and services structuring model, suited for an adaptive dynamic hypermedia system used in delivering courses that reprocess pedagogical items and to allow the distinction between the document contents and its presentation form. The distinction between content - that is concepts delivered in classes and links between concepts - and shape – that is presenting those concepts using didactic items and modeling inter-concept linkages in the shape of hypertext connections - has consequences upon system capacities, besides encouraging teachers to use a methodological approach. Courses should no longer be static, instead they should emerge at the confluence of concepts, relations between concepts and didactic items that teachers refer to. That is the reason why, for example, the addition of a new didactic item will be immediately recorded. Courses will be dynamically built by a system component named “the courses generator”.

2. An adaptive hypermedia system has to support for a resource management aimed at intelligent, student oriented and pedagogical outputs and to allow teachers to share their points of view, giving them the opportunity to benefit from the work of their colleagues. This way the step is being made from sharing didactic items to sharing concepts and inter-concept linkages designated by these didactic items, all those activities being carried out taking into consideration the psycho-pedagogical profile of the student.

3. Identification of new solutions to increase quality of system adaptability is another objective that should be considered. The distinction between content and shape will allow increasing system adaptability. While with classic adaptive systems

the teacher only could interfere in the course, with the new system students should be able to specify some characteristics used by the course generator. Therefore the course should be adaptable by both teacher and student, depending upon the information referred to by the teacher and upon the learning will of the student.

4. Ensuring of global system adaptability is another priority for the dynamic adaptive hypermedia systems. When the system introduces learner profile (level of knowledge, for example), the courses generator will be able to take the new input into account and will modify the courses considering information about the learner. Therefore, the courses produced by the system will depend upon the information given by the teacher, the characteristics given by the learner and the learner profile.

5. Development of intuitive working tools is also a priority. Obviously, facilities of the navigators nowadays allow conceiving a system in which instruments are as applications that can be activated like Web pages and executed inside the navigator. Therefore, simpler and more intuitive instruments can be developed.

4.2 General conceptual models of dynamic adaptive hypermedia

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.

4.2.1 The domain model

The domain model defines the hypertext structure of the system. For its representation a semantic network is used. The concepts of the network are interlinked through four types of relations which allow: *the decomposition of a concept* to be learnt in a succession of concepts; *approaching the same concept* from a variety of perspectives; *the need for a minimal set of previous knowledge* in order to understand the concept, and the *need for support knowledge* to understand other concepts, i.e. to adapt the learner model, which will allow the learner to make analogies between different items of knowledge. Some relations will be weighted and the procedure allows the emphasis of the features. This model aims to assist any teaching agent to access different standpoints on the domain formulated by another teacher, a group of teachers working in the same domain or all the teaching agents.

4.2.2 The learner model

The learner model includes two sub-models: *the epistemic sub-model* and *the behavioral sub-model. The epistemic sub-model* is the component that allows the assessment of the learner's level of knowledge prior to the presentation of the concepts to be acquired in the domain. As this level of knowledge is related to the knowledge presented in the domain model, the epistemic sub-model may be considered a derivation of the domain model. Each concept of the domain model is associated with an epistemic model of the learner through a weighted relation. Thus far, the learning systems have used three types of weighting: binary weighting (the learner either knows or does not know the concept), discrete (defines the category of learner, for instance beginner, intermediate, expert level) and continuous (the values are set in an interval). While the first sub-model presented above is always included in the learning systems, the *behavioral sub-model* may be absent. The intrinsic knowledge of the behavioral sub-model will be organized in three categories depending on the learner's *preference, objectives*, and *intellectual capacity. The learner's preference* will influence the creation of pages that are going to be shown, because when developing her model, the learner will specify the characteristics that will serve the construction of all the pages dedicated to her, and which will define in a sequential manner the organization of information on each page.

Therefore, preferences differ from other components of the behavioral sub-pattern in several respects. Firstly, they cannot be deduced by the system, instead the user has to inform the system directly or indirectly about her preferences (for example, choosing a course text without sound animation). Nevertheless, adaptive systems can generalize the preferences of the users and apply them to new contexts. Secondly, they have a specific modeling and representation characteristic. While other parts of the behavioral sub-pattern are symbolically represented, preferences are almost always numerically represented and calculated. Numeric representation is more advantageous than the symbolic one as it allows combining different attributes (user model) with different users (or with the same user at different times). *The learner's objectives* will influence the system's behavior; the system will have to be more or less flexible and to adopt a more or less flexible standpoint on the organization of knowledge, for instance whether the learner chooses to review for an exam or to deepen her knowledge. The objective of the learner is ephemeral sometimes, as it can change from session to session or even within the same working session. With some systems, a distinction is being made between local or low level objectives which can frequently change and general or high level tasks and objectives, which are more stable. For example, in educational systems knowledge acquiring is a high level objective while solving a problem is a low level objective which can change several times during a session. An objective may be a very important attribute to a user at a certain point of time. The current user objective is often configured similarly to the way her knowledge is configured. In this situation the system bears several tasks and objectives which are likely to appear, and its current objectives are usually represented by a multitude of "objective-value" pairs, the value being the probability for the objective to correspond to the current objective of the user. Finally, the *learner's capacity* will be taken into account not in a global manner, but depending on the type of the subject matter [26]. There is a wide range of cognitive characteristics of the student that should be configured, such as cognitive sensorial aptitudes (verbal, spatial, mathematical and logical, kinesthetic [3]; cognitive style (impulsivity, reflectivity, dependency and independency objects [14] and personality traits (introversion, extraversion). We mention here that, unfortunately, there are very few significant results concerning the use of these characteristics with adaptive systems. Moreover, when trying to make systems based upon individual cognitive characteristics of the users, there is the difficulty of capturing these characteristics and defining some adaptation rules that should use these criteria.

4.2.3 The multimedia database

The multimedia database is the third component of the system. It allows the presentation of each concept and is made up of basic components (teaching items). Each basic component is associated with a concept of the domain model and is characterized by three attributes: cognitive type, cognitive level and physical type. *The cognitive type* allows for the classification of media resources after their educational dimension (e.g. a lecture, a summary, etc.). *The cognitive level* allows the association of a media resource with the level of knowledge necessary for the proper understanding of the information at that level. *The physical type* allows the specification of the multimedia feature of the media resource (text, image, etc.).

4.2.4 The course generator

The course generator differs from the other modules by that it does not integrate knowledge in the proper sense of the word, but it is a system based on inferences from the domain model, the learner model and the basic components. Since the hypermedia consists of pages and connections, as stated above, the course generator will create at a given time the page and the connections associated with it. The construction of a hypermedia page depends on the learner model, i.e. the epistemic and behavioral sub-models, as well as the set of basic components. To this are added three filters which allow retrieval of a number of basic components depending on the cognitive type, the cognitive level and the physical type. Once the content of a page is built, the system must define the hypertext connections which allow the user to access the other concepts. For this, it suffices to rely on the relations of the domain model, the epistemic sub-model, and the type of course the learner wants (i.e. study for examination or free coverage).

Together, the four components lead to the conceptual model of a dynamic adaptive hypermedia system.

4.3 The integration of adaptive hypermedia systems in educational environments

Dynamic adaptive hypermedia systems are a real progress in the field of computer-assisted learning systems. The dynamic aspect allows differentiating between the content of a document and its shape as, on the one hand, such a system includes the domain model which is the raw knowledge in that domain and, on the other hand, the system includes the multimedia database which makes documenting the courses possible. 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 discussed in this paper is different from other hypermedia learning systems for several reasons: it allows filters in order to select media resources useful in concept presentation; it unifies course structure in order to reduce 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.) object-oriented data bases, distributed data bases, etc.

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.

This type of 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 [23] and further developed by Engelström [16] and *Social Networks Analysis*, also known as the theory of structural interactionism, together with informatical 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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