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Why to use a dynamic adaptive hypermedia for teaching, and how to design it?

Nicolas Delestre, Jean-Pierre Pécuchet, Catherine Barry-Gréboval
PSI - INSA de Rouen, BP 08 Place Emile Blondel, 76131 Mont Saint Aignan Cedex, France
Tel : (33) 2 35 52 84 70, Fax : (33) 2 35 52 84 41, E-mail : Nicolas.Delestre@insa-rouen.fr

Abstract : For many years, hypermedia has been a new research area in the field of computer aided teaching systems. Three kinds of systems have successively appeared: first classical hypermedia, then adaptive hypermedia and finally dynamic adaptive hypermedia. Dynamic adaptive hypermedia systems are more efficient, but they are rarely multimedia and hardly ever use the Internet to send courses. This paper begins with a historical reminder then introduces the architecture of METADYNE, a dynamic adaptive hypermedia system. This system allows to create and to distribute multimedia-based courses adapted to the learner, and to transmit courses via the Internet. An open architecture and the respect of standards allow the user to connect to the system with a simple browser, and enable the system to connect a large range of pedagogical multimedia databases.

1. Introduction.

Further ITS (Intelligent Tutoring System) [Baron 95] and ILE (Intelligent or Interactive Learning Environment) [Dillenbourg 93] researches on Computer Aided Teaching have taken an interest in hypertext system. However the main advantage of those hypertext systems, i.e. the liberty of navigation, has quickly become a major inconvenient for many systems (for instance information systems, help systems, research systems, etc.) and especially teaching systems. Therefore, researches have tried to lead the student according to his knowledge, by changing the content of pages and links between pages: adaptive hypermedia was born. But afterwards, other studies have shown that those systems were not perfect. So there is now a third kind of hypermedia system: dynamic adaptive hypermedia system, i.e. systems which build, in a dynamic way, the pages and the links of the hypermedia according to the student's characteristic. The aim of the METADYNE project is to design a dynamic adaptive hypermedia system, which is really multimedia and uses Internet to send the courses.
First we are going to study the advantages and disadvantages of the different kinds of hypermedia systems. Then, we are going to introduce the architecture of our system. To conclude, we will introduce the perspective of our work.

2. The hypermedia systems for teaching.

In this section, we are going to introduce the three kinds of hypermedia systems, defining their characteristics and analyzing their advantages and their disadvantages in an educational use.

2.1. What is a hypermedia system?

The word *hypermedia* is the concatenation of two words : *hypertext* and *multimedia*. A hypertext system is a system that allows somebody to introduce different information in a non-linear way. Hypertext is constituted of nodes and links. The nodes, or the pages, of the hypertext are made up of textual information, and the links allow the user to activate other pages. Hypermedia stands out from hypertext by the contents of the nodes. Nodes are not only made up of textual data, but they are also made up of multimedia data, like pictures, sounds, videos or interactive applications. Therefore, some authors use *hypermedia* or *hypertext* words indifferently to show that the main interest of those systems is not the content but the architecture.

2.1.1. Why to use a hypermedia system for teaching?

In fact, there are two points that encourage authors to use hypermedia for teaching. These two points are the consequences of the architecture of the hypermedia system, i.e. multimedia and hypertext aspects.
First, different researchers tried to estimate the interest of multimedia system for teaching. Then [Hoogeveen 95] emphasised some criterions, like “Level of Multimediality”, “Level of Man-machine Interactivity” and “Level of Congruence” that allow us to estimate the teaching quality of this kind of system. While reading this paper, we conclude that multimedia increases the educational quality of teaching system because visual and play aspects are more attractive for students.
Second, hypertext component can perform educational quality of teaching hypermedia, because the architecture of those systems allows the student to structure his knowledge, to understand better the ins and outs of each concept of knowledge. By the non-linearity of his progression, he has to build his knowledge by creating links between each concept. Indeed, like J.F. Nadeau wrote in [Nadeau]:

> *Learning like thought can not be structured with isolated ideas but with significant or associative links between ideas […] The hypermedia system becomes a tool to structure the thought.*

2.1.2. Why not to use a hypermedia system for teaching?

Those two advantages can become disadvantages, since they are able to disorientate the student, as they introduce too much media to the student we call it: *cognitive surfeit* [Rhéaume 93].
First, the disorientation is the consequence of the opportunity for the student to move in the structures of the system. This freedom risks finishing to cloud him, and the student may wonder some question like “Where am I?”, “Why am I here?” or “Why must I do?”. Rhéaume explains that this is the result of our short-term memory, since as Miller proved it in [Miller 56], human-being are only able to memorize in one moment little information, about seven topics.
Second, cognitive surfeit is the result of the avalanche of information that the system risks sending to the user. Indeed, the redundancy, to be good, must be built in an intelligent way. For instance, the same information must not be introduced to the student with different media which need different levels of knowledge.

2.2. What is an adaptive hypermedia system?

Researchers have tried to minimize negative points of hypermedia for teaching by making adaptive hypermedia. The main goal of this kind of system is to adapt the way to introduce knowledge to the student and to lead the student in the hyperspace[1]. Therefore, in this kind of hypermedia, the system can modify the content of pages and the links between them [Brusilovsky 96]. In order to lead the student, different techniques have been created [Brusilovsky 98]. We can find for instance techniques of direct guidance, adaptive ordering, adaptive hiding or adaptive annotation.
The architecture of adaptive hypermedia systems as in many teaching systems, is mainly based on two models: the domain model and the student model. The domain model represents the knowledge in a rough way, the student model represents student’s knowledge.
There were three generations of adaptive hypermedia system. The first one used the *index page method*, where each concept is connected to a page. Through this page, the user can reach all other pages dealing with this concept. The next generation of systems used an index page again, but those index pages allowed to reach significant fragments of pages. It was called *fragment indexing method*. This technique is similar to the first one, but leads to a more accurate index. The latest generation of adaptive hypermedia systems has based the hyperspace on the domain model structure [Vassileva 97]. Each concept is linked to one or few pages and the relations are represented by hypertext links.

2.2.1. Why use an adaptive hypermedia system for teaching?

Adaptive hypermedia system is better than a classical one because techniques that are used allow the student to be guided without deleting his free navigation, and allow the teachers to structure better their knowledge (mainly in the last generation of hypermedia). Indeed the fact to distinguish the knowledge from the media that will be used to introduce them allows the teachers to structure better their jobs. For that they first organize the knowledge and they think how to introduce it.

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1. The hyperspace is the graph that forms by the page and the links of the hypermedia system.

2.2.2. Why not to use an adaptive hypermedia system for teaching?

However, there are some issues left. First researchers were interested mainly in how to lead the student in the hyperspace, but not in how to perform the content of pages that are introduced to the student. We can explain this established fact because researchers experienced their new technologies on existing hypermedia systems. And it is easier to hide or to annotate links than to replace the element of pages by others. Second, as the courses are not adaptable, in some cases the structure of these courses may change, and therefore disorientate the learner.

2.3. Dynamic adaptive hypermedia for teaching.

As a consequence of the two disadvantages of adaptive hypermedia, dynamic adaptive hypermedia appeared. The main characteristic of this kind of system is to propose to the user a virtual hypermedia [Vassileva 95]. Such systems are not implemented with physical pages: these ones are dynamically built. The architecture of these systems is based on four components: the domain model, the student model, a teaching materials database and a courses generator [Vassileva 92]. The domain model, like the latest generation of adaptive hypermedia, allows to determinate the hypermedia structure. There are therefore two bijections:

- between knowledge concept of domain model and hypermedia pages,
- between relations between those concepts and links between hypermedia pages.

2.4. Conclusion.

During the fifteen last years, researches about hypermedia teaching system have continuously performed different techniques. First, researchers used classical hypermedia system, then they created adaptive hypermedia system and now the focus is on dynamic adaptive hypermedia system.
However, dynamic adaptive hypermedia systems are often dynamic adaptive hypertext systems, but rarely multimedia. Moreover those systems are often private, they are not distributed, they do not use the Internet network.
The goal of our system, called METADYNE, is to be a real dynamic adaptive hypermedia, by taking into account all the characteristics of the user. The adaptation must be effective as many links as content of pages, by using multimedia data to build courses and by using Internet network to distribute them.

3. METADYNE.

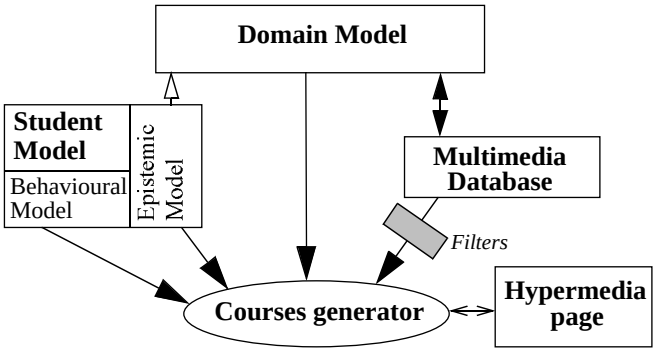

Figure 1 - Architecture of Metadyne

METADYNE is a system of design and distribution of courses via Internet network. In addition to intrinsic characteristics of dynamic adaptive hypermedia systems, it must:

- propose uniform and really multimedia courses,
- take into account the knowledge level of the student as well as his tastes or his goals,
- offer tools allowing to represent the knowledge of a group of teachers, allowing them to put their knowledge in common and allowing the system to perform its adaptation.

As we can see in the figure 1, the architecture of our system is based on four classical components: the domain model, the student model, multimedia database and the courses generator.
In this section, we study these four components, by putting original things forward that will allow us to reach fixed goals. To perform this presentation, we use some examples, from a course about RLC electric circuits. We have made this choice, because we can use a lot of multimedia to introduce RLC electric circuits, for instance textual data for definition or demonstration, picture for electric assembly diagram or vector representation, video to explain how to make electric circuits and simulation software to manipulate virtual electric circuits. Moreover, this course requires many prerequisite, mainly in mathematics and physics, and allows the student to choose different tools to resolve some issues.

3.1. The domain model.

It defines the structure of the hypermedia system. We use a semantic network to represent it. There is an appropriateness between the couple concept-relations of the semantic network and the couple page-links of the hypermedia system. The concepts of this network are linked together with four kinds of relation:

- *is sequentially composed by*, enables to brake up the teaching of a concept into the teaching of a succession of concepts. For instance, a course about derivates can begin with a course about simple formulae, then a course about calculation of derivate functions, and finally a course about slopes of tangent.
- *is derivated in*, enables to show a concept through different points of view. For instance, a course about the light can be a course about corpuscular theory or about ondulatory theory.
- *needs the knowledge of*, enables to select what has to be known to understand the concept. For instance, courses about derivates and limits are prerequisites of a course on asymptotes.
- *is able to be helped by the knowledge*, allows to urge the student to go and see one concept as well as to initialize user model on the current concept. For instance, having the knowledge of the Pascal language can be considered as an advantage while learning the C language.

The two last relations are weighted. These weights allow the system to lead better the student in the hypermedia system. For instance the system considers that a student needs to revise a prerequisite if his mark is lower than the weight coefficient of the link.
Finally, we consider that it is important to provide to the teachers a way to put their knowledge in common, allowing each one to preserve his own vision of the model. Therefore, with this model, we want each teacher to be able to access to the different points of view about the model (i.e. the point of view for a given teacher, the point of view of a group of teachers and of all the teachers). So each concept, each relation and each weight coefficient are labeled. This kind of annotation has two main advantages. First, each teacher can estimate his vision of a domain model according to his colleagues' vision. The second advantage concerns the student: the system can choose different pedagogical strategies. For instance, if the student wants to consult a course for an exam, the system will mainly use the point of view of the teacher that will give him a mark. On the other hand, if the student freely uses the system, then the system will let him have a larger vision on the subject.

3.2. The student model.

Besides the domain model, a good representation of student model is essential. As researches about user model is a full filed of artificial intelligence, our aim is not to perform existing model. So we decided to use a model introduced in [Nicaud 94] and [Balacheff 92]. This model is made up of two sub-models: an epistemic model, and a behavioural model.

3.2.1. The epistemic model.

This model allows the system to know what the learner is supposed to know or not to know. As this knowledge is closed from the knowledge represented by the domain model, the epistemic model can be regarded as a derivative of it. Then each concept of the domain model is linked with the epistemic model of the learner by a weighted relation. Until now, teaching systems use three kinds of weights [Brusilovsky 96b]. There are binary weights (the learner knows or does not know the concept), discrete weights, by defining different categories (for instance, novice, middle, expert), and continuous weight (values are chosen between two extremes values). It is this last technique we decided to use because we think it is the most efficient one. Moreover, it is the only one that allows the system to take time intp account an easy way, and time is a parameter that we decided to use (the idea came from mnesic network of [Jorion 89]). Indeed, to

perform our epistemic model, time is considered as a variable of forgetting, because everybody who does not revise regularly a knowledge, may forget them partially or totally. Finally, the system does not confuse its ignorance and learner's ignorance.
To resume, our epistemic model exists by relations that are built between itself and the domain model. These relations are weighted with a value. They underscore what the system knows about the learner's knowledge about one concept. This value is either "I ignore the state of the learner's knowledge" or "I know the state of the learner's knowledge" and in this case a real value is associated, proportional to the level of the learner's knowledge, and updated according to the date of the last rereading of the concept.

3.2.2. The behavioural model.

Whereas the epistemic model is always used in teaching system, the used of behavioural model is often limited or lacking. Our adaptive system wants to be as near as possible the student, i.e. the system must take into account his preferences, his aims and his intellectual abilities.

- The student's preferences will have an impact on the organization of course pages. Indeed, while the student profile is initialized, student will set all the characteristics of what we call the 'canvas'. This canvas will be used as a model to define the structure of all the courses that will be introduced to the student.
- The student's goals will have an impact on the system behaviour. Indeed, as the student wants to revise for an exam or not, the system will have to be more or less flexible.
- The student's ability will be taken into account, not in a global way, but in changing the model according to the teaching subject. Then, depending on the subject, the system will suppose or require a specific level knowledge for the student, and in the same way the temporal weights of the epistemic model will change according to the subject.

To finish, let us notice that those two sub-models are intimately linked. For instance in the epistemic model, the temporal variation of weights is according to the behavioural model.

3.3. The multimedia database.

The third component of our system is the multimedia database allowing the system to introduce every concept. This database is made up of "elementary brick". Each brick is associated with one concept of the domain model. They are characterised by three attributes : the cognitive type, the cognitive level and the physical type.

- The cognitive type allows the system to sort media according to their teaching nature (for instance an introduction, a definition, an exercise, an abstract, etc…). That allows to get hypermedia pages that follow the structure of the canvas.
- The cognitive level allows the system to associate a media with a knowledge level that is required for a good understanding of the information introduced.
- The physical type allows the system to specify the multimedia quality of each media (text, picture, video, interactive application, etc…). This attribute allows once again the system, when it built a hypermedia page, to follow instructions defined in the behavioural model.

Moreover, [Recker 95] proposes to associate in an intelligent way physical and cognitive types. For instance, it is preferable to use textual media to introduce examples, annotations or definitions. But it is preferable to use sound media to introduce abstract or to warn the user.
To finish, this database will be able to be local, away or distributed. That allows the teachers to use his elementary bricks or to use elementary bricks that will be placed in another server, for instance SEMUSDI [Delestre, Rumpler 98].

3.4. The courses generator.

This last component builds the pages that will be introduced to the student. Its job is to:

- As soon as the student has chosen the course that he wants to follow (in our case the course about Force damped oscillator), the system selects the good concept in the domain model.
- Then, the system takes the canvas of the student (from the behavioural model) and gets his knowledge about the chosen concept (from the epistemic model).
- Then, the system chooses the various media to introduce the concept according to the structure of the canvas, and the student's preferences (from the behavioural model). This selection is the result of the use of three fil-

ters. The first one sorts the elementary bricks according to their cognitive type, the second one according to their cognitive level and the last one according to their physical type. If the selection does not allow the system to choose an elementary brick, the system can deactivate the filters and begins by the last one.

- Then, the system determines the relations according to the domain model, the student's knowledge (epistemic model) and the student's goals (behavioural model). For instance, in our case, for the demonstration about the calculation of phase difference between the intensity and the voltage, the system will be able to activate two different prerequisite relations (either on mathematical concept of Fresnel construction or on mathematical concept about complex number).
- To finish, the system builds the hypermedia page (HTML page) and sends it to the student.

The student actions (for instance when he clicks on link or when he resolves exercise) allow the system to update the current student model and to propose another page.

4. Conclusions and perspectives.

Dynamic adaptive hypermedia systems are a real new way of researches compared with the other computer aided teaching system. Although the architecture of our system looks like the architecture of some another system, it stands out by:

- the use of filters to choose the media that allows to introduce the knowledge with the better way,
- the standardization of course structure thanks to the use of canvas,
- our will that the adaptive system takes into account not only the student knowledge, but the student preferences and goals too (the system is not only an adaptive system, it is an adaptable system too),
- our will to offer to the teacher a tool which allows them to put their knowledge in common.

Until now, we have mainly worked on the SEMUSDI Server, on the global design and on the object design of METADYNE. Now, we work to resolve technical issues, and mainly on communication between the client and the server (between JAVA applet and the server). We have the opportunity to test our system with the student of the INSA of Rouen.

5. References.

[Balacheff 92] Balacheff N. (1992), Exigences épistémologiques des recherches en EIAO, *Génie Educatif* (4).

[Baron 95] Baron M. (1995), EIAO quelques repères, *Revue Terminal*.

[Brusilovsky 96] Brusilovsky P. (1996), *Adaptative Hypermedia : An Attempt and Generalize*, P. Brusilovsky, P. Kommers, N. Streitz (Eds.), Multimedia, Hypermedia, and Virtual Reality (1077) 288-304. Berlin: Springer-Verlag.

[Brusilovsky 98] Brusilovsky P. (1998), *Adaptive Hypertext and hypermedia*, Kluwer Academic Publishers.

[Delestre 97] Delestre N., Gréboval C., Pécuchet J.P. (1997), METADYNE, a Dynamic Adaptive Hypermedia System for Teaching, *3rd ERCIM Workshop User Interfaces for All, 143-149.*

[Delestre, Rumpler 98] Delestre N., Rumpler B. (1998), Architecture d'un Serveur Multimédia pour les Sciences de l'Ingénieur, *NTICF'98, Rouen*, 39-46.

[Dillenbourg 93] Dillenbourg P. (1993), Evolution épistémologique en EIAO, *Ingenierie Educative, Sciences et Techniques Educatives*,(1), 39-52.

[Hoogeven 95] Hoogeven M. (1995), Toward a New Multimedia Paradigm : is Multimedia Assisted Instruction Really Effective ?, *Proceedings of ED-MEDIA 95 World Conference on Educational Multimedia and Hypermedia*, 348-353.

[Jorion 89] Jorion P. (1989) *Principe des Systèmes Intelligents*, Science Cognitive.

[Miller 56] Miller G.A. (1956), The magical number seven plus or minus two: some limits on our capacity for processing information, *Psychological Review*,81-97.

[Nadeau] Nadeau, F. Application et impacts de l'hypermédia constructif sur l'apprentissage, *http://www.fse.ulaval.ca/fac/ten/64448/nado/semi.html.*

[Nicaud 94] Nicaud J.F. (1994), *Modélisation du raisonnement algébrique humain et conception d'environnements informatiques pour l'enseignement de l'algèbre*, Scientific rapport, LRI, Paris XI.

[Recker 95] Recker M. (1995), Cognitive Media Types for Multimedia Information Access, *Journal of Education Multimedia and Hypermedia*.

[Rhéaume 93] Rhéaume J. (1993), Les Hypertextes et les Hypermédias, *Revue EducaTechnologie*, (2).

[Vassileva 95] Vassileva J. (1995), Dynamic Courseware Generation : at the Cross of CAL, ITS and Autoring, *Proceedings of the International Conference on Computers in Education, ICCE'95*, Singapore, 290-297.

[Vassileva 97] Vassileva J. (1997), Dynamic Courseware Generation on the WWW, *Proceedings of the workshop : Adaptive Systems and User Modeling on the World Wide Web, Sixth International Conference on User Modeling*.