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Development of New Media Didactic Systems
with an Interdisciplinary Approach

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***Abstract* - The purpose of this paper is to introduce an interpretation model for the deployment of new media in didactics, taking inspiration from theories coming both from Didactics and Semiotics. State of the art experiences are analysed, in order to evaluate and settle novelties and limits in an adequate context. Finally, the project of a new didactic system is described. This system takes advantage from the expert systems technology and from the latest media format research (MPEG-4 and MPEG-7). It exploits the potential of the new media in terms of enhanced dynamic hypertext navigation and interactivity through the use of semantic data.**

***Keywords* - didactics, Internet, distance learning, multimedia, expert systems, interactivity, student model, MPEG.**

I. Introduction

"First we shape our media, then they shape us." This sentence by Mc Luhan [1] describes what is nowadays happening with the introduction and spread of the new media in all fields of human communication and consequently of man's everyday life. These changes, often labelled as revolution, can have no little influence on didactics.

In fact, expressions like "distance learning" and "online courses" are gaining more and more trust both in didactics and technology. The improvements new media can bring in this field, and even more in higher education, are actually relevant. Positive experiences are already on the run and important issues are being investigated.

Nevertheless, the new technologies and the Internet have been created as information systems and need a further work in order to support real education systems. On the other side, some key-words like multimedia or interactivity are still vague, both as general definitions and in relation to particular domains like that of didactics.

The research presented in this work takes advantage of an interdisciplinary approach: a theoretical model of didactic communication was developed, starting from items both from communication theory, semiotics and didactics. This model provided categories for an effective analysis of current distance learning experiences in higher education. The information gathered was the starting point for requirement analysis and specification of a new didactic system that exploits state-of-the-art expert systems and multimedia technologies.

The theoretical model developed was used as framework for the deployment of an advanced navigation engine for didactic hypermedia applications. As it concerns navigation and guidance, the system is named Seaway Tracker.

II. Didactical-Communicative Framework

In this context, a great number of projects are expected to bring a revolution in higher education. In spite of this, the mere implementation of multimedia internet-based learning programs does not imply automatically the appearance of new adequate scientific concepts [2]. The need for an adequate framework considering technical, technological, didactical and pedagogical issues is perhaps the most explicit requirement for a new scenario in learning. The risk of a big-effort small-result "technology for technology's sake" should be feared: technology can be exploited only if its instrumental vocation is taken into account and aims to accomplish specific purposes in each domain.

A scientific basis for defining a possible framework is the model of communication proposed in 1960 by Roman Jakobson, the Czech semiotician founder of the School of Prague [3] (See Figure 1).

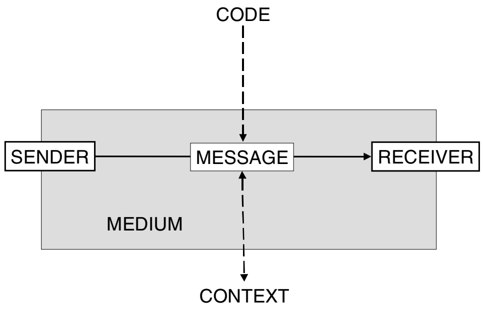

Fig. 1: A graphical representation of Jakobson's model.

This model, one of the most productive ones in the history of Linguistics and Semiotics, describes communication as the result of the interaction of six elements. The SENDER (or addresser) generates a MESSAGE with a specific purpose and content. It is made for a RECEIVER (or addressee), who is supposed to be interested in the actual communication. The MESSAGE is phrased using a specific CODE, which offers particular expression possibilities and limits. The transmission happens through a MEDIUM that can ease or disturb communication. The MESSAGE refers to some real-world object and makes sense in relation to that specific CONTEXT. The actual meaning and success of any single communicative act depends on the interaction between all of these elements. Whenever a single element remains latent a complete successful communication cannot be achieved.

Moreover, a communicative act can focus particularly on one of these elements. This allows Jakobson to define six different communicative functions:

1. SENDER: emotive function;
2. RECEIVER: conative function;
3. MESSAGE: poetic function;
4. CODE: meta-linguistic function;
5. CONTEXT: referential function;
6. MEDIUM: phatic function.

Jakobson [3] gives a complete description of the model.

We propose to consider learning as a special kind of receiver-oriented communication, that is a communication with conative function, defined by a reflexive characteristic: the agreed communicative purpose is the RECEIVER's understanding of the content of the communicative act, in order to let him acquire some new knowledge.

In more detail, in the context of higher education, the knowledge (the MESSAGE) can be categorised into four main categories [4]:

1. Scientific Knowledge: the declarative knowledge, i.e. the "pure" information;
2. Scientific Competences: the know-how of the methods to acquire scientific knowledge;
3. Meta-Knowledge: the reflexive knowledge of the value of gained declarative knowledge;
4. Meta-Competences: the competence of choosing and evaluating different methods and procedures.

Any of these categories includes both content and values. It is clear that only some of these types of knowledge are completely at reach just relying on the performances of a medium: a complete didactic communication can be achieved only in a complete face-to-face didactical interaction. Rephrased, a medium can reach positive goals and exploit its features only if driven by the intention of a "teacher".

The RECEIVER, i.e. the student, is supposed to have some characteristics in order to play his role in this new context. These characteristics are an abstract model of students. Each student has different characteristics and his own way of studying. On the other hand, institutions could see this model as a summary of technology-related goals for primary education, a sort of computer schooling. They can be summarised in four main points [5]:

1. Self-learning: manage independently the study activity;
2. Team working: get and keep in touch for a collaborative work with other people;
3. Flexibility: find, use, and understand different media and contents;
4. Media-skill: both using and evaluating new technologies as well as the information that they make available.

The role of the student becomes more and more important: his ability to give himself a precise aim and to have a defined question in the act of learning is as much as decisive[1] as the confidence with the new learning context [6]. We consider these characteristics as granted in a normal higher education situation.

The real change new media bring involves the medium, which gets more importance through enhanced performances (multimedia, quick electronic communication, etc.). The code, as usual, complies with the possibility the medium offers. As a consequence, the sender plays a minor role: he interacts much less with the receiver, as part of the mediation is taken by the medium. On the other side, the receiver's role in decoding and understanding the message is necessarily more active.

Increasing the complexity of the MEDIUM affects the balance of the whole communication system. A highly technologic didactic system integrates many functions, and this means an incredible increase of expressive and communicative power by supporting many different message types, codes, interaction patterns, etc. This incredible growth of complexity is allowed by the possibility new technologies offer to structure interaction: an application provides a communicative framework that guides an activity through pre-defined paths and steps, making it more effective. Consequently sender and receiver must be able to manage all the new complexity

[1] Prerequisite for this is the motivation to study, of course.

not to get lost in the growing information flow. This can happen:

- Through a loss of reference: the more communication grows, the easier it is to forget the real world reference and remain entangled in the net of signs;
- Through false interactivity: a complex medium can simulate the effects of personal communication and become the excuse for dropping interpersonal communication.

In didactic systems both risks would lead to lose the interpersonal relationship between teacher and student, i.e. the heart of education, as seen before. To keep communication successful and sane, the actors, sender and receiver, have to learn how to control and exploit the medium according to their communicative purpose.

Concluding, the new media bring only a partial change in didactics and not a revolution in the process of learning. Furthermore, a good framework for the introduction of new media must take into account the "traditional" elements and methods of didactics, which do not lose their value and have to be relocated to play a new role in a new context. Moreover, learning cannot be flattened to a mere transmission of information, but must be considered as a complex communicative situation: where technology often plays the main role, the difference between *information* and *education* must be always kept in mind.

III. ACTUAL ON-LINE DIDACTIC SYSTEMS: NOVELTIES AND LIMITS

The next step was to prove the adequacy of this didactical-communicative model (see Figure 1) to the state of the art of information systems with didactical purposes. To accomplish this task, some on-line courses have been analysed and actually "attended". An evaluation grid was made to facilitate the observation[2], focused on system structure (both on-line and off-line components), use of multimedia and flexibility.

The great majority of the tested courses showed a similar structure, and did not dare to use more complex and powerful systems than HTML websites.

The analysis revealed both positive ideas and problematic aspects. Main issues are:

1. *Interactivity*: the new media are often defined as interactive media. This definition must not be mixed up with normal face-to-face interaction, where an optimal level of communicative relevant information flow can be reached. The new media are interactive if compared with a book or television. A certain part of this new interactivity has actually been reached, mostly via e-mail with the teacher. Efficient systems sometimes lack effectiveness: for example, to cope with the large number of students attending the course automatic mailing has been used. This means reducing the framework of interaction to formal basis, such as reading a certain page or submitting a form. The reduction of the role of the SENDER detected in the model presented in Figure 1 shows its consequences here;
2. *Active Learning*: The more decisive role that the RECEIVER has to play is encouraged by the choice of active learning strategies. This happens mostly by creating learning-by-project courses [7];

At the same time, some limits of almost all systems emerged from the analysis:

1. *Low (or absent) real Interaction:* the interactivity most courses offer happens on a formal basis, and does not originate from the meaning developed in the didactical communication. Simple questions like "Would you explain it in another way?" or "I do not understand" are normally impossible. Asynchronous interaction modalities are sometimes possible, such as per e-mail. However, this depreciates on-line lessons. The new role of the RECEIVER is consequently still more difficult: he has to face the same complexity of a subject (the MESSAGE) not supported by the mediation possible through direct interaction.
2. *Static Structure:* on-line courses always have a static structure, even if some of them show a more or less complex hypertext structure. The content does not adapt itself to the needs of the student. This is what a teacher normally does, when answering even simple questions like "Would you make an example, please?" Face-to-face interaction allows a continuous re-structuring of the content, which is a main condition for understanding. This issue is faced in the hypermedia community as well. The latest trend in hypermedia research and production is a paradigm shift: creating a hypertext is no more considered something like writing a multi-linear text, but a completely different job. It consists in preparing content units (or nodes) and rules for navigating through them. The user or reader then has the duty to choose a fruition (navigating through hypermedia reading contents) strategy. A linguistic comparison: "the hypermedia author does not produce a text neither a number of texts, but sets of syntactic rules and basic elements", like defining a kind of high level language [6].
3. *Unstructured multimedia content:* Multimedia offers great possibilities in learning: a consistent and controlled use gives the possibility of improving learning through multi-modality and multi-coding. The deployment of multimedia is actually not completely exploited. This happens both for reasons of network performance and for cultural reasons: there is actually a lack of a method for teaching with multimedia. A great push in this direction would be given by the possibility of handling multimedia contents on a semantic basis, not only on formal ones. This would allow handling content slots not like black boxes, but with a formal description of their actual content. In Part VII we describe a technical possibility for multimedia exploitation in the Seaway Tracker system.

[2] An accurate and most possibly complete analysis of fewer cases has been preferred to an overall and forcedly formal statistical analysis of a greater number of experiences.

These limits make it difficult to develop didactical systems providing real education services instead of just information transmission. The difference lies in a defined purpose shaping the relation between the communication partners.

IV. The Seaway Tracker Didactic Expert System

The Seaway Tracker project is currently developed at the Università della Svizzera italiana (USI) in Lugano, faculty of Communication Sciences, with Marco Colombetti[3].

A first development phase has been concluded with a small exploratory prototype in February 1999. A first version of the complete project will be ready in June 2000 in collaboration with the Politecnico di Milano[4]. This phase will be concluded with the production of a prototype suitable for testing. The final complete implementation and production of the course (as CD-ROM and/or on-line) is scheduled for 2001.

The objectives of the project have been specified in the framework of the model presented in the previous section. The main goal is creating a didactic system with the following main features:

- The explanation can be adapted to the needs of the student, in terms of quantity and complexity of information delivered per time and of expository strategy;
- Real interactivity is offered, concerning the semantic structure of the content;
- Multimedia content is handled on the basis of semantic information, so that it can be highly integrated and exploited in the didactic interaction.

Seaway Tracker is basically an expert system that models the didactical interaction as a complex action with a defined purpose ("That the student learns a certain content"). A deliberative agent [8, 9] plans its action working on a semantic net. A complex data structure, the *Knowledge Base* (KB) of the system, allows him to generate an explanation suited to the current situation. The KB contains both dynamic data and static data. The planning activity is executed according to pre-defined didactic strategies. The system can be used both off-line as stand-alone application and on-line by adding a network interface. The prototypes were realised with Java. The system can be sketched as in figure 2:

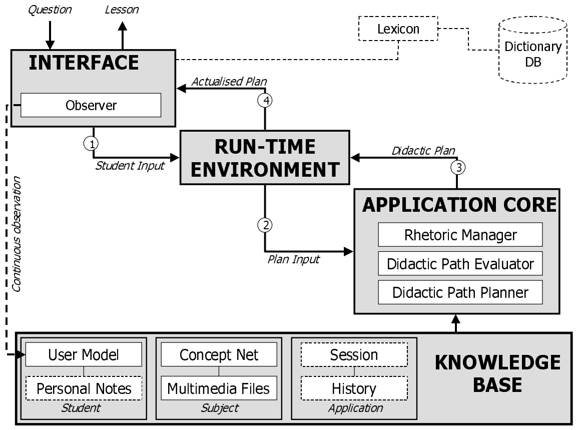

Fig. 2: Overview of the Seaway Tracker System (bold line: main modules; thin line: internal parts; dotted line: optional modules and dynamic data)

A. *Knowledge base (KB)*

The KB (technically an object-oriented database) stores the knowledge the system requires for planning didactical interactions. It contains three different kinds of data:

About the student:

1. *User Model:* contains profiles of the students, including preferences, favourite learning strategy and interests. These models are created partially via an "application form", but mostly via run-time observation of students' learning activity (see *Observer*). Students' knowledge of the subject is modelled by a Bayesian network, which allows a precise update after each session.
2. *Personal Notes:* students can underline sentences and jot down remarks that can be stored and displayed in the next sessions.

About the subject:

1. *Concept Net (C-Net):* here is the core knowledge the system uses. It is a representation on the subject as a three level hyper graph: the main nodes are concepts and arches are connectors. Concepts are clustered in islands (upper level) and connected to multimedia files (lower level). Several kinds of concepts and connectors have been defined, each with a different semantic value. A first description of the net has to be given by an expert[5]. In a second step an inference machine can establish new connections.
2. *Multimedia Files:* each concept in the C-Net is mapped to a multimedia entity [10] composed by different media slots. Entities can be of several types such as explanation, author biography, on-line evaluated exercise or off-line exercise, evaluated by the teacher.

[3] Two target courses have been chosen: that of *General Linguistics* held by E. Rigotti in Lugano and the one in *Knowledge Engineering* by M. Colombetti.

[4] In collaboration with P. Paolini, C. Accursio and P. Mazzoni.

[5] In the project in Lugano, S. Cigada, teacher in Linguistics.

About the application:

1. *Session:* gathers all useful data concerning the actual session, such as a detailed session history, a list of all interactions, etc.
2. *History:* contains the history of the system and a summary of all previous sessions per student, i.e. presented information and exercise marks. This allows the system to remember what a student knows and to calibrate future explanations.

B. Application Core

This is the part of the system that is based upon the KB data, and develops an adequate didactic plan, suited to the needs and possibilities of the student. Its main logical parts are[6]:

1. *Didactic Path Planner (DPP):* receives the input and finds all the possible ways from a concept the student already knows to the grade of the session (see *Interface*), in relation to all session constraints. The planning activity is hierarchical and exploits the three granularity levels offered by the C-Net structure. Once all the relevant concepts are found, these are ordered according to some didactic strategy, such as "from an example to the theory" or vice versa, or "presentation by a problem", etc.
2. *Didactic Path Evaluator (DPE):* given some student-related and session-related criteria, selects the best didactic plan and let it be actualised.
3. *Rhetoric Manager (RM):* details the concepts in the plan into a sequence of multimedia files (nodes) to be actually presented to the student. The activity is lead by several rhetoric patterns, i.e. possible presentations of the same concept given different available multimedia files.

C. Interface

The interface has three main functions:

1. Get the required input for each session. It means to set:
   - The grade, i.e. the purpose of the learning activity: answering a question about a concept, getting information about an author, simply going one step further, etc.
   - The constraints, i.e. how much time is at disposal, what degree of complexity can be reached, etc.
   - The modality, i.e. the type of study activity the student wants, such as studying new things, repeating for the exam, making exercises, etc.
2. Actualise didactic plans, by displaying the actual multimedia content and allowing navigation;
3. Offering non-imperative semantic-oriented interaction modalities, such as the possibility to ask for a different explanation of the same concept (e.g. through another didactic path) or for a summary, or simply stating non-understanding. The student has therefore the possibility to ask a question, and not to use the imperative mode typical of human-computer interaction.

An important module in the interface is the *Observer*: it observes the students during the learning activity and stores relevant data for their knowledge acquisition and for their profile, such as a ranking of didactic strategies and media that improve the understanding rate, or defining a competence level for certain content types.

D. Other modules

- Runtime Environment: variables and processes necessary during the execution.
- Lexicon: a simple language analysis (optional) module, capable of recognising synonyms, opposites, etc. and to map them with the concepts stored in the C-Net. This improves interactivity (it is possible to explain the same concept with different words) and search possibilities.

Of course, the complete system has to offer static ready lessons as well, for beginners or in case the student has no particular question.

Despite the complexity of the knowledge representation model, the system is mainly subject-independent. Only high-level concept and connector types have been defined, with the possibility for each author to define his specific types.

V. Example

During the analysis of real on-line courses, *InterQuest*[7], a basic course in philosophy at Oregon University, was one of the most interesting solutions available. A part of the second lesson in this course, "The Power of Inquiry", was "translated" to be stored in the KB. Figure 3 shows the explanatory path actually presented on the web. Each box represents a HTML page and each arrow a hyperlink. Although a small hypertext navigation possibility is given, the general structure is fix and linear. At the end of each page some feedback about the level of understanding was required through a form.

The same concepts would be organised in the KB as shown in Figure 4. Each box here represents a concept, which would be mapped to different parts of multimedia content[8]; each arrow represents a semantic connection between two concepts. The labels indicate the connector

[6] For performance reasons these parts are actually integrated in one module. Their functions can be nevertheless logically separated.

[7] The course is "telematically" held by J. Dorbolo. http://osu.orst.edu/instruct/phl201/

[8] For simplicity's sake, just one general type of concept was used. The system supports actually different types of concepts, defined by different parameters (difficulty, importance, etc...) and consequently differently managed in planning the didactic interaction.

type: ISA means an "is a" relation, where the lower concept is a specialisation of the higher one; VS means "versus", that is the concepts are logically opposites; PT indicates "part of" (meronimy), where the lower concepts are parts of the higher one; TW means twins: the concepts are to be explained together for a better understanding as they are somehow same-level concepts[9].

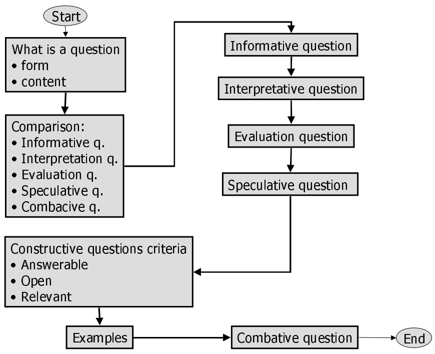

Fig 3: Structure of a part of the second lesson of InterQuest.

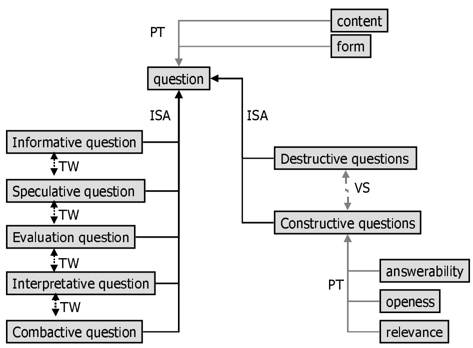

Fig 4: The same lesson of InterQuest as structured in the Seaway Tracker KB.

The Seaway Tracker System would receive an input from the student, for example "In the domain of questions, what is relevance?" The reaction would be generating a didactic path leading from already known concepts to the required one. The result is a linear lesson, composed by concepts (the mapped multimedia contents are shown) and connectors (phrased in natural language).

The structure of interaction has been actually built on student's needs. He would have the possibility to ask for a new explanation because of non-understanding: a new path could be generated, a different multimedia presentation shown or a connector rephrased. A new form of new media interaction is available, which is semantic-oriented and didactically relevant.

[9] For simplicity's sake, no parameters were used in describing connections as well, and only some of the connector types have been used here.

Developing a course with a system like Seaway Tracker means a completely different job than translating a book into a more or less complex hypertext structure. To a certain extent just a conceptual description has to be given in a synchronic way, without considering the normal diachronic i.e. temporal development of the teaching activity. During the fruition, the student is in charge of creating a precise didactic sequence of concepts. The sender can play a less active job because the receiver is able to play a more active one, involving his decision and freedom. A system like Seaway Tracker takes advantage of the new situation brought by the new media, providing an efficient tool to support didactic communication. This does not mean it is a complete education system, but only a factor in the whole complexity shown in the model of figure 1. Any didactic technology requires in fact the integration in a complete didactic and pedagogic management.

VI. Limits & Future Developments

The Seaway Tracker research right now has reached a first phase of maturity. Some intrinsic limits deserve attention for planning further developments.

First, the system addresses only the moment of personal study, not any other common educative dynamic such as direct interaction with the teacher or collaboration with other fellow students. Moreover, programming an actual on-line course with the system is no easy matter, as no authoring interface has yet been designed. Consequently, two goals will be addressed in the short term:

1. *Report Module* that allows the teacher to get up-to-date reports about the status of each student and of the class in general;
2. *Authoring Interface,* allowing a teacher to define concept and connector types, modalities and constraints and to connect the system to a multimedia content database.

Systematic testing on the new prototype will give new hints for identifying limits and possible improvements. Observing the differences in deploying the system in different subjects will be the most valuable source of information. As stated in part II, the next part gives a more detailed overview of multimedia integration in the system.

VII. Multimedia Standards for Representation, Storage, Delivery and Interactive Use: MPEG-4 And MPEG-7

We describe here currently available technology for a future improvement of the system.

The ISO/IEC Moving Picture Experts Group (MPEG) developed with MPEG-1 and MPEG-2 the most important standards for coded representation of moving pictures, audio and their combination. These are standards with much influence on the development of digital video and television systems all over the world. The newer developments, namely MPEG-4 and MPEG-7, are not intended as an extension or enhancement for MPEG-1 or MPEG-2, but their scope includes completely new application areas and possibilities.

MPEG–4, Multimedia Application Standard

MPEG-4 builds on the proven success of three fields: digital television, interactive graphics applications (synthetic content), and interactive multimedia (World Wide Web, distribution of and access to content). MPEG-4 provides the standardised technological elements enabling the integration of the production, distribution and content access paradigms of the three fields.

For authors (the SENDER in the model of figure 1), MPEG-4 enables the production of content that has far greater reusability, greater flexibility than is possible today with individual technologies such as digital television, animated graphics, World Wide Web (WWW) pages and their extensions. [11].

For the receiver (or the student in this context), MPEG-4 also brings high levels of interaction with content, within the limits set by the author.

In respect to the network, MPEG-4 offers transparent information, which can be interpreted and translated into the appropriate native signalling messages of each network with the help of relevant standards bodies. This, however, excludes Quality of Service (QoS) considerations, for which MPEG-4 provides a generic QoS descriptor for different MPEG-4 media. [12].

In this way, it is our choice for an important part of the MEDIUM in the theoretical model. In our proposal, we use MPEG-4 for:

- Representation of all possible media objects, using AVOs (audio-visual objects);
- Description of composition of these objects to form audio-visual scenes;
- Multiplexing and synchronisation of the data associated with media objects to transport it over networks, providing QoS appropriate for the nature of the specific media objects;
- Interaction with the audio-visual scene generated at the student's end.

MPEG-7, Multimedia Content Description Interface

This standard is also called the content representation standard for multimedia information search, filtering, management, and processing [13].

While it is not yet a finalised standard, available proposals have been used to obtain an impression of what could really be meant when speaking about context information and semantic managing of multimedia content. With this kind of information about the media objects (meta data), we are able to:

- Enhance search strategies, making it possible to search within audio-visual media objects;
- More highly integrate multimedia in the planning activity;
- Decide on different display properties;
- Make consistency checking;
- Provide scalability based on consistency and priority information.

In this way, the MPEG-7 context data is intended for integration and enhancement of the MPEG-4 format discussed before by adding metadata to AVOs.

The use of MPEG-4 and MPEG-7 introduces relevant semantic description of multimedia contents in the system, further improving interactivity. Semantic data are in fact directly linked to the content.

VIII. Related Work

The research in didactic application of new technologies produced many results. Brusilovsky [14] gives a general overview with the description of thirteen new systems.

Two common ideas in this research field are user profiling and the separation of logical content structure and hypermedia documents. For example, the AHM (Adaptive Hypermedia Model) system [15], developed at the Leuven Catholic University exploits a structure based on topics and documents; a more complex system, the Hyperbook [16], developed at the Hannover University, structures content as a net of tasks, projects and concepts. Most systems exploit link annotation for guiding students. A good example of this technique is AHA (Adaptive Hypermedia Architecture) [17].

Among didactic systems, Seaway Tracker presents two main novelties:

1. *Semantic Planning*: the system computes using the semantic description of the content, not just annotating links, but actually producing navigation plans;
2. *Hierarchic Content Structure*: i.e. a precise definition of levels. Planning exploits the different granularities (actually Islands, Concepts and Nodes), supporting scalability by introducing new hierarchic levels.

Two other researches in didactic systems exploit the same ideas as well: the iTeach [18] system and the DCG (Didactic Content Generator) [19], both developed in Germany.

IX. Conclusions

The new possibilities offered by the new media are not fully exploited in this domain, partially because of a technological gap between the world of education and that of technology. A further reason is the different curricula and social environment, precisely concerning media and technology, of teachers and students. Interdiscisearch

plinary models can allow a better understanding of the introduction of new media in the society.

In the field of didactics, the model proposed here helped to get a precise insight of the main issues related to new media. The analysis revealed both positive trends and problems, and supplied guidelines for the development of a new didactic system. In the future a precise observation and evaluation of the results gained with the new system will be a precious source of information. New trends in multimedia research will probably offer new tools and ideas for further improvements.

The challenge is still open both in fundamental and applied research. New media bring new opportunities and new risks in all communication fields: the goal is to make them serve important human communicative and collaborative processes so to improve our life. This means a great work, and requires new responsibilities to be taken.

The complexity and importance of didactics make it one of the favourite domains for this challenge.

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