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HIERARCHICAL MULTILEVEL APPROACH IN HYPERMEDIA INTELLIGENT SYSTEMS FOR MATHEMATICAL MODELING

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Abstract: Since ancient times, models have become widely accepted as a means for studying phenomena, but the processes involved in the mathematical modeling formulation continue being complex and ill-structured problem. For many years Methodologies of mathematical modeling have tended to concentrate the effort on taxonomies more than to the formulation stage of the modeling process. At the present paper, the analysis and formulation modeling stage are discussed. In this relation, a new method for problem solving based on a Hypermedia Intelligent Tutoring System is proposed. The system acts like a tutor helping students to model and solve optimization problems under complex decisional situations. In this connection, the Systems Theory and its methods for the HITS design are implemented. The system was implemented in C++ and Delphi on microcomputer.

Introduction

The improvement of modeling teaching using the concepts, approach and tools of hypermedia intelligent tutoring systems (**HITS**) is the main goal of the present paper. Teaching and learning process is constitutes by a set of activities, which have passed throughout the mankind history a long and complex improvement process. Since transmission of empirical knowledge from parents to children in ancient times to computer assisted learning at the present time.

The teaching and learning processes have a complex and dynamic character. His fundamental elements are: the teacher and the student. They relations are dynamics. The

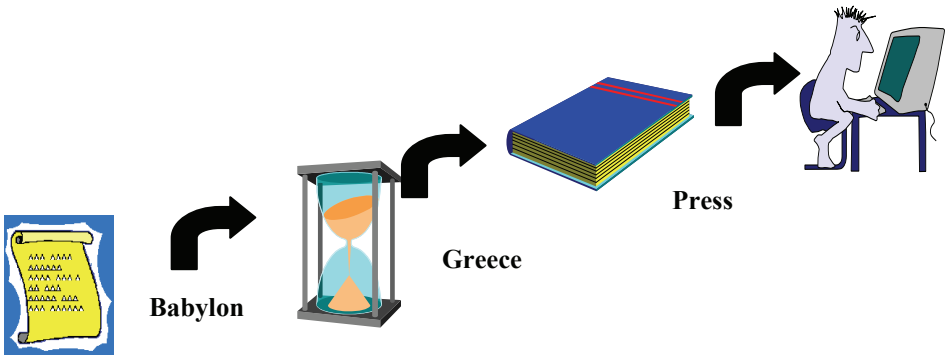

Fig. 1 Teaching development in different stages of history

feedback is dynamic too. The feedback is produced by the observation on behavior and knowledge control of students. These elements can be analyzed by parts of a cybernetic system. From one part, the teach transmits the knowledge, skills and habits to student. From the other side, the student catch the transmitted information, selects it and saves in his memory. In these conditions, we can define the education like the process of interaction between a subject and a object, in which are developed in the object (student) and improved in the subject (teacher) knowledge, skills and habits. Since ancient times human being has used media to show new ideas, to give evidences and to persuade. Learning and Teaching Media permit: 1) a best comprehension of transmitted information; 2) Improve the knowledge control; 3) Automation of complex and laborious processes. On this basis, the cybernetic diagram can be completed by addition of learning and teaching media. In this connection, we have the following figure:

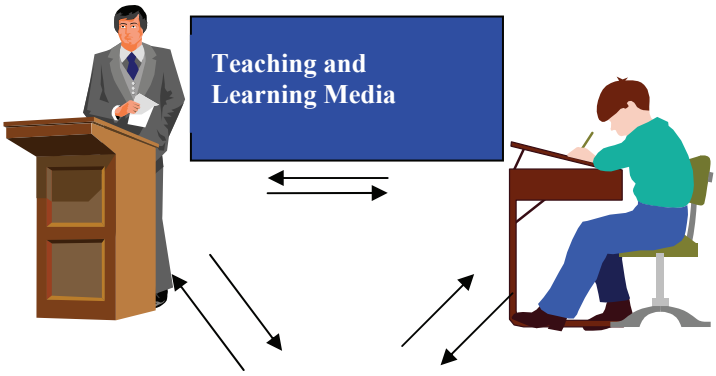

Fig. 2 Cybernetic System

Every day, the contradiction between the time dedicated to prepare a professional and the information volume is more important and sharp. To increase the study time is irrational. In this connection, it is necessary to improve the efficiency and quality of teaching and learning process at universities. The computer education presents some advantages, between them are: 1) the development of modeling and algorithms of subject matters; 2) more efficient knowledge transmission; 3) the possibility of analyze complex and dangerous phenomena; 4) the visual representation of objects; 5) dynamic interaction with the information source, which permits the selection of multiple decision alternatives.

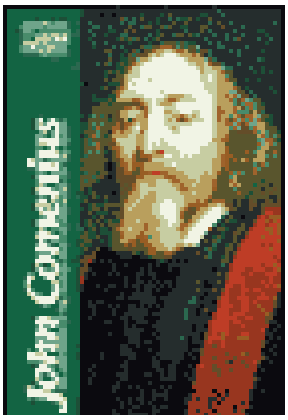

Fig. 3 J.A. Comenius and Didactics

Comenius realized serious contributions to Didactics. He defended the ideas of dynamic interaction between students and teacher and on the visual representation of objects. A graphic is more efficiency than discourse. See[1]. The intelligent tutoring systems or computer based knowledge systems can adapt his behavior, results and knowledge presentation to student necessities, abilities and behavior. Some evaluations of HITS show the students can acquire the same master level or domain of subject matter in 1/3 of required time using conventional teaching methods and these systems increase the student learning efficiency in approximately 40%. See [2].

Design criteria

We established as the main HITS design criteria the following: 1) Development of Systems Approach; 2) Analyze real world cases; 3) Introduction of AI techniques and methods; 4) Use of hypermedia and multimedia in system modeling; 5) Design of graphic interfaces.

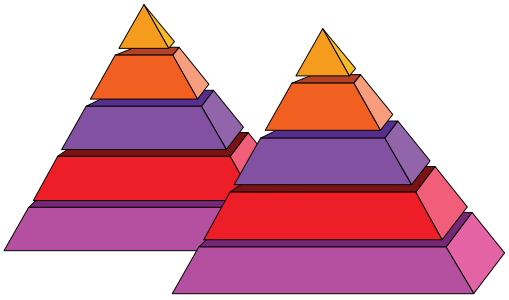

Fig. 3 Multilevel hierarchical systems conception

Mathematical Modeling Teaching

The teaching process must guarantee the development of modeling skills. In model building, we start with a construction of a verbal model for the real system and then refine it until it can be translated into mathematical language. The real problem in translation from the verbal model to the mathematical statements arises when the initial verbal model is not an adequate description for the real system, and the shortcomings of the verbal model are revealed in the attempt to translate. The student must know the main characteristics of different optimization models and to be able to establish the main differences among them. These statements make evident two of the main problems on Mathematical Modeling: 1) the establishment of adequate relationships between the real system and verbal model (**idealization process**); 2) the translation from verbal model (word problem) into mathematical model. In this relation, the idea on the design of a Hypermedia Intelligent Tutoring System (HITS) for Mathematical Modeling Teaching was implemented. In this paper we present a version of a HITS for student training in the formulation of optimization models and the problem identification. First, the acquisition of skills on idealization of phenomena by students constitutes a complex and slow learning process. See [Hickman [10] , Wagner[5], Ackoff [ ]]. Second, for most students working with algebra expressions and solving equations (i.e. Simplex Method) becomes rather easy with practice and repetition. The part of Mathematical Modeling course, they find most difficult is the mathematical formulation of verbal models (word problems), because, they need to translate the verbal model into mathematical model. The OR teaching experience shows, that frequently, the students are in trouble in determining the most adequate model when they face a complex

decision problem. In OR , it is not evident the selection among the known methods (i.e. linear programming, dynamic programming, simulation and so on), for determining which is the most efficient. Nowadays, beginners in model building are helped by experienced tutors or experts, in their facing with decision problems of high complexity. In this relation, we decided to develop a HITS for Mathematical Modeling Teaching.

The system acts as a tutor helping student to formulate the mathematical model of different optimization problems an to identify the more rational algorithm of solution. The students using it can learn and develop modeling skills interacting with a computer. The successful development of this software require to find a rational solution to the following problems: 1) How the students select the best algorithm?; 2) How the students develop their modeling skills?. The solution to these problems determine the specific characteristics of the designed software package. This package permits the knowledge and experience of many teachers (experts) to be hold in a computer. This knowledge can be used by students requiring it. The propose of Optima HITS is not to replace the OR teachers, but simply to make their knowledge and experience more widely available. HITS increase students and teachers efficiency, improve the quality of their decisions or simply permit to solve problems when the teachers are not available. Valuable knowledge is a main resource and it often lies with only a few teachers. It is important to capture and store that knowledge. It is the domain of the best and more experienced teachers. The best teachers can die, retire, get sick, move to others fields, and otherwise become unavailable. Thus knowledge is lost. HITS provide a direct means of applying the teachers' expertise. Typically, there are more problems to solve than experts available to handle them. HITS permits students and teachers to increase their productivity, improve the quality of their decisions or simply to solve problems when the teacher is not available. Valuable knowledge is a main resource and it often lies with only few teachers. HITS provide a direct means of applying the teachers' expertise. The system was implemented on C++, Delphi and Java. Its main component are: Hypermedia Problem Generator, Problem Classifier, Expert, Tutor, Optimization Solver, Comparator and Debugger. Step by step Optima takes you on an exciting session through the world of model building. You can see factories, transport systems, ports and machines. You can hear the motor sound, dangerous signals, and advices.

Hypermedia Intelligent Tutoring Systems

Based on the ideas stated above, the problem that concerns us now is the following:

- **How to solve it?**

The improvement of the teaching process under given condition must follow the way of strengthening the relationships among production activities and OR teaching process. This process must guarantee the development of modeling skills in translating from the reality into the verbal model, and from the verbal model to mathematical model. The student must know the main characteristics of different optimization models and to be able to establish the main differences among them. The main goal can be accomplished by means of practical activities in the enterprises and in the development of projects in which the students be trained constructing production and service optimization models of real systems. In the paper, a new software package that allow the computer to act as a HITS is proposed. The students using it can learn and develop modeling skills in interaction with the software system. The successful design of software package requires to find a rational solution to the following problems: 1) How the students can select the best algorithm?; 2) How the students can develop their modeling skills?.

The solution to these problems will determine the specific characteristics of the software. The second problem is more easy to explain. We can define it as an expert system. The system permits the knowledge and experience of many teachers (experts) to be captured/stored in a computer. This knowledge can be used by students requiring it. The

purpose of a HITS is not to replace the OR teachers, but simply to make their knowledge and experience more widely available. Typically, there are more problems to solve than experts available to handle them. HITS permits students and teachers to increase their efficiency, to improve the quality of their decisions or simply to solve problems when the teacher is not available. Valuable knowledge is a main resource and it often lies with only a few teachers. HITS provides a direct means of applying the teachers' expertise. From our point of view a HITS include modules explicating knowledge about areas: hypermedia problem classifier and generator; teaching domain; expert; student model; debugger; user interface.

Hypermedia Problem Classifier and Generator

The selection of specific word problems based on students performance will improve the HITS quality. In this relation, the bank (stock) of word problems is divided into classes or complexity levels depending of difficulty or complexity of its solution. The usual way of dealing with word problems for a voluminous and complex problem is to divide the system situation (general problem) into many subproblems (divide and conquer). Word problems that are included in a class should be selected in accord to its "similarity". Expert and teaching criteria determine the complexity of word problems. In each case the student's task consists in diagnosing or revealing, what kind of problem is and to determine which is the optimization model more efficient or adequate in the particular decision situation. He must decide based on the main characteristics of statement if the proposed word problem is a: transportation; assignment; blending; and/or other problem. According to OR teaching experience and practice a software package based on Systems Approach was designed. In other words, for each class or complexity level were proposed word problems, in which the student is encouraged to compose and decompose different real systems. The teaching goal consists in teaching the systems approach's scientific method. Figure 5 shows a hierarchical

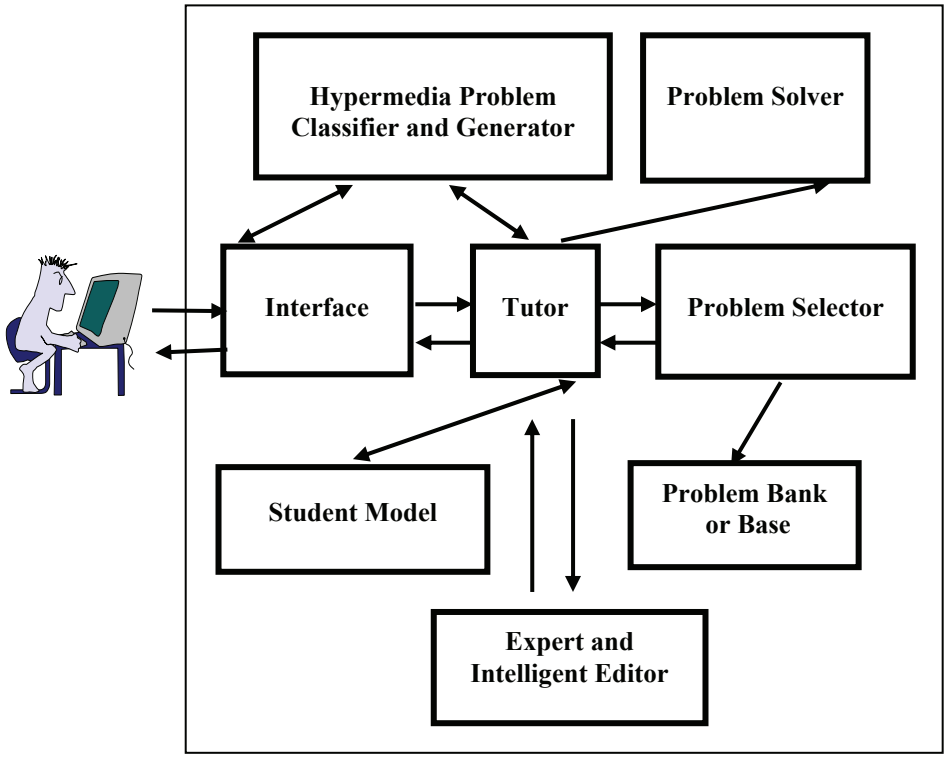

Fig. 4 Optima: A Hypermedia Intelligent Tutoring System

multilevel representation of the sugar cane factory. Related with it several word problems associated with each representation stage (or layer) can be proposed to the student. Only by learning the isolation, decomposition – composition concepts and the hierarchical representation of systems, students would obtain a clear idea of the optimization problems and finally get its entire domain. In this connection well known Cuban educator and philosopher Luz y Caballero argued: "... **It's necessary to round the nature to domain it. If we concentrate our efforts in the guess more than in the observation, the phenomena essence slips away, and if we want to limit our analysis to a simple observation without all possible elements, comparisons and evaluations, never we'll reach to comprehend the inside of the phenomena and never we could to understand certain complex laws: the nature require and encourage us: Divide et Impera" [9]**. Then he says: **"To well synthesize it's necessary to analyze firstly" and "When decomposing I become to compose, or to see the thing in the all and its parts, that it is just we can define as science".**

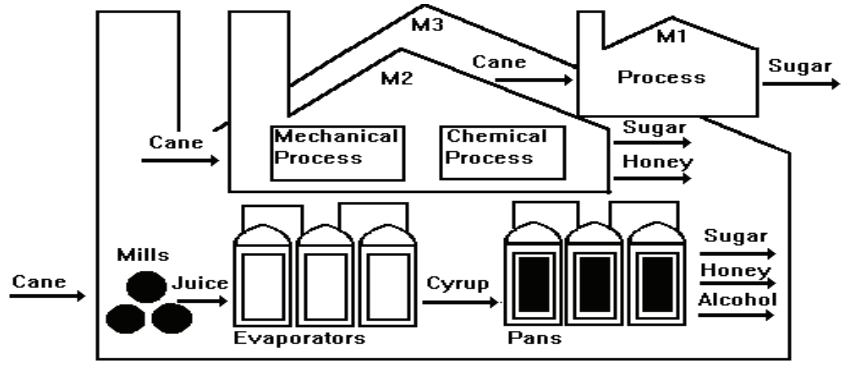

Fig. 5 Hierarchical multilevel representation of a sugar cane production system

The designed Hypermedia Problem Classifier and Generator contributes to reach the teaching goal. The student can analyze several problem representations by means of video, photos, graphics, animations and sound. This facility improve students relations with the reality and its modeling. The student actively participate in a Cognitive Experiment. He can change several structural components of the problem and study its characteristics under different conditions. As a result of this process, the students can "touch with their self hands the reality" trying to model it. This process to make deeper or more profound their knowledge on modeled "real phenomena or systems" in magnitude and complexity. The students can move from one node (problem statement) to another in accordance with their learning objectives or goals. A problem statements' graph was designed. The root node is the "biggest problem statement". The interior nodes are coupled problem statements and their children represent their subproblems or components. The set of problem statements represents the most general problem situation and the interior nodes are the based on Systems Approach. In this relation, the student knowledge could be increased step by step from one node to another. This design element is very important in order to increase the quality of HITS.

Expert

The expert module contains the knowledge about the subject area (Optimization Models) we want to teach. Drawing on this knowledge the system should be able to answer the student's questions and give him guidance. Here, one should strive for deep structure knowledge instead of surface knowledge. In the case of OR this module includes the knowledge that an expert uses when he selects the best solving method. The acquisition of this kind of knowledge is extremely difficult, but this "implicit knowledge" should be made

"explicit" in order to be taught. A forward chaining mechanism for the machine engine was designed and implemented.

The proposed method provides questions about OR models and it recommends the more rational solution for the given conditions. The knowledge base has been built through interactions with OR professors. This body of knowledge is represented as a collection of conditional sentences called "production rules". An example is shown below:

R1: IF
The problem exhibits feature X
and
The problem exhibits feature Y
THEN
We may conclude that the likely model is of type A

R2: IF
the model is the type A
and
the problem does not exhibit the feature Z
THEN
we can conclude that the problem
is not likely to be described by the model B

It was supposed that we have a set of optimization models. This means we can solve each selected model using the Solver module. This Solver has the required algorithm to solve them. In this relation certain number of model classes were established. For example:

- Production systems
  - Production assembly lines problems;
  - Production distribution planning problems;
  - Resource assignment problems;
  - Blending and diet problems;
  - Location – investment problems;
  - and others.
- Transportation problems;
- Assignment problems;
- Route problems;
- and others.

Experts goes from the general questions to more detailed questions. In the last time, we thank on the possibility to develop an intelligent editor. Its objective is to precise the expert work and help students in mathematical model formulation. In this relation, a new module for determining the mathematical model of proposed problem was designed. The intelligent editor encourages the student to find the mathematical model helping him in this complex task by means of warnings and commentaries. Finally, when the student has edited his mathematical model version the editor compares it with the expert formulation and explain the student its characteristics.

References

1. Comenius, J.A. "Complete Works". 1657.
2. S. Lajoied and A. Lesgold "Apprenticeship Training in the work place: Computer-Coached Practice Environment as a New Form of Apprentice ship", in Intelligent Instruction by Computer: Theory and Practice, J. Forr, and M.J. Psotka, eds. Taylor and Francis, Washington D.C. 1992.
3. Descartes, R. "The rules for the domain of reasoning". 1628.
4. Sleeman D.H., Assessing Aspects of Competence in Basic Algebra, Intelligent Tutoring Systems, Sleeman D.H. and Brown J.S. (eds), Academic Press, London, Great Britain, 1983. pp. 185-199.

5. Wagner H.M., Fundamentals of Operations Research, Addison-Wesley, 1975.
6. Burton R. R. Diagnosing Bugs in Simple Procedural Skills, Intelligent Tutoring Systems, Sleeman D and Brown J.S. (eds), Academic Press, London, Great Britain, 1983, pp. 157-183.
7. Goldstein I.P. , The Genetic Graph: A representation for the evolution of procedural knowledge, Intelligent Tutoring Systems, Sleeman D.H. and Brown J.S. (eds), Academic Press, London, Great Britain, 1983, pp. 51-77.
8. Santamaría, M.A. and Garay Garcell M.A. "Systems Theory in the Mathematical Modeling Teaching". International Systems Journal. Spain Society of General Systems (SESGE). ISSN: 0214-6533. Vol. 4, No. 1-3. Madrid, Spain. Jan-Dec., 1992.
9. Luz y Caballero, José de la. Notas filosóficas de José de la Luz y Caballero. Impugnación a las doctrinas filosóficas de Victor Cousin. Pág. 67-71. Editorial Universidad de La Habana. 1948.
10. Hickman, Frank "Application of A.I. techniques to formulation in Mathematical Modelling". The Fifth International Conference on Mathematical Modelling in Science and Technology. Berkeley. California. U.S.A. July, 1985.
11. Smith Gerald F. "Towards a Heuristic theory of problem structuring". Management Science, Vol. 14, No. 12. U.S.A. 1988.
12. Clancey W. "Tutoring rules for guiding a case method dialogue" pub. in Intelligent Tutoring Systems (Sleeman D. & Brown J.S.). U.S.A. 1982.
13. Garay Garcell, Miguel. Iskusvennyi Intellet i Modelirovanie. Escuela Internacional de Computación. Varna. Bulgaria. Junio/1989.
14. Garay Garcell, Miguel. Artificial Intelligence and Mathematical Modelling. Seminario de Inteligencia Artificial. Universidad T,cnica de Helsinki. Helsinki. Finlandia. Octubre/1990.
15. Garay Garcell, Miguel. La inteligencia artificial en la ense¤anza de la Modelación Matemática. II Congreso Mundial de Educación y Entrenamiento en Ingeniería y Arquitectura. Palacio de Convenciones. Ciudad de La Habana. Cuba. Septiembre/1991.
16. Chiang Carbonell, Luis A. Programa Clasificador de Problemas. Ponencia presentada en el Congreso de Informática Educativa, Informática' 94. La Habana, 1994.
17. García, de la Vega Dalia M. Hipertextos e hipermedia. Conferencias Curso de Informática Educativa, ISPJAE, 1994.
18. Hernández, Asdrúbal. Diseño de una interfaz para la solución de problemas de optimización, I.S.P.J.A.E. Julio, 1995.
19. Quang, Nguyen Thuong. Máquina de Inferencias para el Sistema Optima, Trabajo de Diploma. I.S.P.J.A.E. Julio de 1995.
20. Shapiro, Stuart (Eds). Encyclopedia of Artificial Intelligence. A Wiley-Interscience Publication. E.U. 1990.
21. Ackoff R.L. Scientific Method. Optimizing Applied Research Decisions. Chapter 4. Models. Operations Research Group. Case Institute of Technology. John Wiley & Sons, Inc. N.Y., London, Sydney. 1962.

Иерархический многоуровневый подход к математическому моделированию в гипермедийных интеллектуальных системах

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Ключевые слова и фразы: теория систем, интеллектуальные системы обучения, мультимедиа, машинное обучение, искусственный интеллект.

Аннотация: Начиная с древних времен, модели широко использовались как средства изучения явлений, но процесс, вовлеченный в математическое формулирование моделирования продолжает оставаться сложной плохо структурированной проблемой. На протяжении многих лет методы математического моделирования имели тенденцию концентрировать внимание в большей степени на таксономиях чем на стадии формулирования процесса моделирования. В данной статье обсуждается анализ и этапы формулирования моделирования. В связи с этим для решения проблемы предлагается новый метод основанный на гипермедийных интеллектуальных системах обучения. Система действует подобно репетитору, помогающему студентам моделировать и решать проблемы оптимизации в сложных ситуациях, связанных с решением задач. В этой связи выполнены теория систем и ее методы для проектировки гипермедийных интеллектуальных обучающих системы. Система была выполнена с использованием C ++ и Delphi на микрокомпьютере.

Ierarchischer vielschichtiger Standpunkt zur mathematischen Modellierung in den hypermedien intellektualen Systemen

Zusammenfassung: Von alten Zeiten an wurden die Modelle als Mittel der Erkennung der Erscheinungen benutzt. Aber der in die mathematische Formulierung der Modellierung hineingezogene Vorgang bleibt ein schweres schlechtstrukturiertes Problem. Viele Jahre lang hatten die Methoden der mathematischen Modellierung eine Tendenz, die Aufmerksamkeit im großen auf den Taxanomien als auf dem Stadium der Formulierung des Prozesses der Modellierung zu konzentrieren. In diesem Artikel wird die Analyse und die Etappen der Formulierung der Modellierung besprochen. In diesem Zusammenhang wird für die Lösung dieses Problems eine neue auf die hypermedien intellektuellen Systemen der Ausbildung gegründete Methode vorgeschlagen. Das System funktioniert ähnlich dem Repetitor, der den Studenten die Probleme der Optimisierung in den Komplexsituationen, die mit der Aufgabenlösung zusammengehängt sind, zu modelieren und zu lösen hilft. In diesem Zusammenhang sind die Systemtheorie und ihre Methoden für die Projektierung von hypermedien intelektuellen Lehrsystemen erfüllt. Das System wurde im Programm C++ und Delphi im Mikrocomputer erfüllt.

Approche hiérarchique à plusieurs niveaux envers le modélage mathématique dans les systèmes intellectuels hyper-média

Résumé: Dans cet article sont discutés les problèmes de l'analyse et des étapes du développement de la méthode du modélage. Les modèles étaient toujours utilisés pour étudier les objets et les phénomènes, mais souvent ils se caractérisaient par la complexité et la mauvaise structure. On propose une nouvelle méthode fondée sur les systèmes intellectuels hyper-média de l'enseignement qui aident les étudiants à modéler et à résoudre les problèmes de l'optimisation dans les situations complexes. Pour la conception des systèmes intellectuels hyper-média de l'enseignement sont élaborées la théorie des systèmes et ses méthodes. Le système a été réalisé dans le programme C++ et Delphi sur le microprocesseur.