E-Knowledge Management: Its Role for the Development of Intelligent E-Learning Systems

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Human expert behavior has always been a key element for the design and implementation of powerful Intelligent E-Learning Systems (IeLS). So far the modeling of this behavior has been very limited. The paper describes another model of expliciting human expert behavior. The model is composed of two related elements: the representation of the scientific knowledge used by the expert, and his experience. The first element is a full graph that includes not only sintactic but also semantic and pragmatic information of the scientific domain; the second element, ia an experience management (Knowledge Management) system that includes all the cognitive elements used by the human expert in the execution of the expert tasks, which should be previously elicited. Human expert mental models play an important part in the obtainment of the true and complete experience of the expert. Similar procedure can be used to model the student behavior, making easier the detection and analysis of the student´s errors, as well as his/her motion along the learning path. Results obtained with a specific IeLS, show a promising perspective.

Keywords knowledge management; intelligent learning systems; multi-agent systems; e-learning;

1. Introduction: Knowledge Management and E-Learning

Electronic Knowledge Management (EKM), and Electronic Learning (EL) are two relatively new fields of application, apparently not very related, but with interesting feedbacks among them that enhance their utility and power up to limits not very well defined yet. They have common features and probably the most important ones are that they all deal with complex problem solving and they are all supported by web technologies for the Inter and Intranet.

The two disciplines, EKM, EL, can be exercised without the help neither of networks nor computers and, as a matter of fact they do have been in the past, with the simpler names of Knowledge Management, Learning or Education with the subtitles of Computer Assisted Instruction, Intelligent Tutoring Systems, Sales Management, etc., but nowadays it is difficult to think of an intensive or extensive application of those matters without computers and networks, and specifically without the web technologies for the Inter and Intranet.

During the last fifteen years, due to the use of Multi-Agent Systems, important changes have been produced in the field of E-Learning and Intelligent Tutoring Systems, leading to a new generation of Intelligent E-Learning Systems (IeLS). The flexibility and robustness of the cognitive agents infrastructure, and the use of cognitive modelling have allowed a big increase in the full functionality of those systems, ranging from the automatic update of Knowledge Bases from the Internet, to the automatic design, management and contro of learning elements for the transfer of novices into experts.

The paper presents the use of some techniques related to Knowledge Management leading to a precise representation of the human expert knowledge and experience, and the student's model.

2. E-Knowledge Management and Experience Management

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The term Knowledge Management was coined more than ten years ago with different meanings; all of them share a core idea but many of them highlight a different aspect and probably a specific viewpoint. E-Knowledge Management (EKM) will add to those definitions the concrete feature of using IT for its purpose.

For the purpose of this paper we may convene that EKM deals with the ways to capture, grow, explore, generate, engineer and maintain their knowledge for the purpose of: learning, decision making, solve problems individually or cooperatively, mainly by making use of the connectivity provided by web-based technologies such as those provided by Internet and Intranet [1]. The field of EKM is very broad, this is why it has to be considered within one or several specific scenarios, such as diagnosis of certain technical equipment, electronics design, electronic commerce, etc., sometimes with a concrete name as customer relationship management; but besides its large scope, new problem areas are arising, closely related if not included in a general KM context. Among them, *learning organizations*, *corporate memory, and experience factory* have to be cited.

EKM is a scientific discipline which can be considered as a combination of methods and concepts from different areas such as computer science and specifically knowledge-based systems and Artificial Intelligence, business process reengineering, human resource management, and organizational behavior analysis.

Experience Management is a particular type of Knowledge Management, restricted to only experience, and as we shall see later on, experience can be human or machine experience. Experience is always a specific knowledge as opposite to general knowledge with a much broader scope; general knowledge is also processed according to different patterns. By experience we mean the specific knowledge acquired by an agent (human or not) during past problem solving. Knowledge can deal with a specific and concrete issue located in a very narrow situation. It behaves like facts, valid or related to a concrete specification. On the contrary, general knowledge produces statements valid within a broad field of application, usually more than a single domain. Often it is obtained as the result of an inductive or generalization process starting with specific knowledge.

Several models, already developed, could be basically modified and used for experience management [1], depending on the emphasis that different authors can do on particular aspects of KM although all of them attempt to capture, collect and share the institution knowledge by making use of the connectivity provided by web-based and intranet technologies. Models are usually powered by methods, dealing with specific details of the knowledge process and tools to ease the data processing aspects of the problem. The most important models dealing with experience management are: the Organizational Memory Model for the organization of the company memory and organizational learning, the Experience Factory for the development of a set of product according to the customer needs, and the Quality Improvement Paradigm for the continuous improvement of a factory quality.

3. The Role of EKM in the Design and Implementation of IeLS

We think that the full elicitation and modelling of human expert knowledge and experience, as well as their implementation, are key points for the design and construction of a new generation of powerful IeLS, based on Multi-Agent Systems. The reason for that approach is that the obtainment of the complete knowledge and experience of human experts and their ingredients constitute the full map of cognitive components that have to be acquired by the student. Therefore they are also an integrating part of a cognitive student model, that also shows the lacking components and methods to become an expert. On the other hand the comparison of the expert and student' behavious allow not only a shallow but also a deep error analysis leading to an appropriate diagnose of the learning situation.

Within the NEOCAMPUS2 Methodology [2], [3], we have developed The Experience Management Model (EMM) that relates the different tasks involved in experience management. It is composed by a knowledge kernel and two shells around it. The knowledge kernel contains not only the experience base but also the use-related knowledge including the vocabulary. The next shell around the kernel consists

of the problem solving cycle including: the problem acquisition, experience evaluation and retrieval, experience adaptation, and experience presentation. All of them are supported by experience reuse with the help of IT.

The outer shell of the EMM is the development and maintenance methodology. The knowledge kernel and the problem solving cycle are the subject of the development and maintenance methodology. The diverse processes that occur in this shell address the acquisition and maintenance of the knowledge in tha kernel as well as the technical, organizational and also managerial aspects of the problem solving cycle and its implementation. The processes occurring in the development and maintenance methodology are not easily automated by using IT technology, although some aspects of them can be partially supported by different kinds of tools. Those processes are also integrating a cycle which must be started each time a kind of maintenance is required. The cycle differs from the problem solving cycle in different features; the former is executed as seldom as possible but the latter is executed as often as possible.

The problem solving cycle supports complex problem solving by providing appropriate experience. It contains the following elements:

-Complex problem identification; it assists in identifying a problem for which assistance is required.
-Problem acquisition module; with it the problem is elaborated and described.
-Experience evaluation and retrieval; the available experience in the Experience Base is evaluated and retrieved with respect to whether it is appropriate to support solving the particular problem.
-Experience adaptation; the retrieved experience is further tailored to suit the current problem.
-Presentation module; the fitted experience is presented to the user during further problem solving.

The cycle must be initiated several times addressing a different subproblem that occurs during problem solving.

The Development and Maintenance Methodology cycle includes several processes in order to acquire and update the required experience knowledge and to customize the problem solving cycle, and requires modeling and maintenance of the experience kernel. The main aspects to be covered by this cycle are the following:

-The process of project management, including cost and resource assessment, time schedules, project plans, quality control procedures, etc.
-The specification of the different kinds of products or deliverables that must be produced.
-The process of product development and maintenance, including all technical tasks that are involved in the development and maintenance of the software .
-The analysis and organization of the environment in which the system should be introduced.

The referred processes can be classified as:

-Technical processes; describe the creation or modification of the experience management software components or the represented knowledge.
-Organizational processes; address those parts of the user organization’s business process in which the software system will be embedded.
-Managerial processes; provide an environment and services for the development of software that meet the product requirements and project goals, such as project planning, monitoring and quality assurance.

All the processes are integrated in the following cycle:

-Vocabulary Development and Maintenance; is a very crucial task since the knowledge containers rely on the vocabulary.
-Development and Maintenance of Reuse-Related Knowledge; involves modeling knowledge for assessing the relevance of an experience item for the actual problem. It can be made based on the similarity between the current problem and the problem in which a particular experience item was collected. This process also includes modeling adaptation knowledge represented in the form of rules, operators or constraints.
-Experience Base Development and Maintenance; initially performed by transforming and integrating existing experience sources like Data Bases, documents or Web resources. If no such sources exist a manual experience acquisition process must be established and integrated into the existing problem solving process.

The EMM has been complemented with several techniques for knowledge representation, that will be briefly explained in relationship to the human expert domain and the student's model.

1)The human expert domain contains not only the scientific knowledge corresponding to the disciplines which are based the domain on, but also the behavior and experience produced or accumulated by human experts during the efficient domain problem solving or task execution to be learnt. The final explanations of the expert behavior to be given to the student, require the justification by means of fundamental knowledge; also the obtainment of the profound error diagnose needs the finding of the lacking fundamental knowledge to choose the suitable remedial tactics.

The main system components that represent the human expert behavior are:

1a-The domain conceptual graph. The graph describes the scientific knowledge related to the ability or the task to be learnt. Its nodes are concepts, relationships or domain properties. Methods, tools and techniques (tactics) are associated to the nodes or arcs of the graph. It includes semantic information connecting the graph constituents to the reality of the ability to learn or the problems to solve, and also pragmatic information with details concerning the utility, efficiency and convenience to use methods, tools and techniques at any specific situation.

1b-The human expert experience management system. The essential ingredients of this component are the families of the human expert mental models [4], [5], [6]. Each family contains similar models (the same goal) but with increasing complexity due to the number of variables and circumstances included in it. Each family is represented by means of a full graph, where each model contains only a subset of the full set of the graph nodes.

Each model is attached to a set of problem solution schemes. Each scheme contains the procedures, methods and tools (behavioral or cognitive) for solving a concrete problem according to the machine learning technique known as Case-Based Reasoning.

1c-The relationships among the families of mental models and among those families and the domain conceptual graph. These relationships can be changed dynamically by the same system according to experience.

1d-The strategies to choose the suitable mental models, to reason with them and solve problems. Some strategies try to match the present problem to an identical or closest problem contained in the problem solution schemes. In the case the selected scheme do not correspond to an identical problem the scheme has to be modified to reach the solution according to different heuristics. The simplest one (closest neighbor) applies the operator that transforms the given problem into the closest one attached to an existing scheme.

1e-Tactics and strategies for learning the different elements contained in the domain conceptual graph as well as in the human expert experience management system. Some times the human expert is fully aware of those tactics and strategies, but in many cases they have to be designed and constructed by means of experience.

2) The student behavior or student's model can be represented by means of, at least, the following components:

2a-The student initial knowledge and basic cognitive abilities before initiating the current learning process.

2b-The student history of the interactions with the system, including all features and details, such as: time of the beginning and ending of each session, items analyzed, number and types of errors committed and the times elapsed from the initiation of the session, questions or exercises solved, help provided, tutorial actions offered, pro-actions suggested, etc.

2c-The student cognitive model representing the student mental state and integrating the student profile. It is a dynamic vector that represents, among other particular aspects, his/her degree of interest for the subject, the student motivation, his/her capacity, attention, sureness, efficiency, emotion, the actual degree of tiredness and the possible presence of psychological problems (without converting the system into a psychological counselor). The profile also describes some other student features coming from his log history such as: error rate per session, total number of errors per type, percentage of session time at which the error frequency is higher, number of problems or questions correctly solved, and rate per

session… Those numbers establish a student learning path, which usually is stable. Sudden changes in the path will provide information concerning possible problematic changes in the student mental state.
2d-The student acquired knowledge and abilities; it is represented by means of a domain conceptual graph, similar to that of the human expert, showing besides the initial student knowledge and basic conceptual abilities, the concepts, relationships, properties and all the declarative knowledge and abilities learnt by the student and the lacking knowledge, procedures and tools. Attached to the nodes and arcs in the graph are also included the methods, procedures and tools mastered by the student. A special key will indicated the level of expertise acquired by the student for the execution of any procedure and the date for this acquisition. In the case the student does not analyze, solve or execute any other problem or exercise related to that procedure, the elapsed time after that date will automatically decrease that level of expertise and efficiency. This change tries to reproduce the real process of the human mind.
2e-The student acquired experience; it is also represented, step by step, by means of an experience management system. The system stores for each task executed or problem solved the solution scheme used. Initially the schemes are not attached to any mental model or to only one complex model (this is typical in apprentices, not in experts), but due to the experience in getting the solution for suitable problems or executing appropriate exercises, the mental models are starting to be built by the student.

4. Results and Conclusions

The NEOCAMPUS2 Experience Management Model and its techniques for representing human expert knowledge and experience, as well as the student's model, have been inherited by all its spin-off systems. FINANCE, a system devoted to Financial Accounting and Business Analysis, is one of the NEOCAMPUS2 spin-off; it has been in operation in real courses for more than two years. The results of the evaluation of FINANCE have been published here [7]. According to them we can draw the following conclusions:
-The elicitation, modelling, management and implementation of the human expert knowledge is a key point for the design and development of Intelligent Learning Systems.
-The results so far obtained, show that Experience Magement is an important issue for the acceleration of the transfer of novices into experts.

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