A MULTI-AGENT ARCHITECTURE FOR MOBILE SELF-TRAINING

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Abstract: This article is the result of an interdisciplinary meeting between sociologists and didacticiens on the one hand and data processing specialists on the other hand. To develop the theoretical and methodological principles of the design of a training environment, by putting the needs and the difficulties of the student at the center of the design process and data-processing modeling, constitutes the common action of these two research laboratories within the framework of this collaboration. To design a virtual tutor called "teaching agent" in a system of remote formation implies the implementation of a flexible and adaptive system. We propose an multi-agent multi-layer architecture able to initiate the training and to manage a teaching and an individualized follow-up.

1 INTRODUCTION

A Computer Environment of Human Learning (EIAH) is a computer system which has for objective to favor the learning of a domain of knowledge by a learning. The computer systems of the learning assistant are traditionally structured around an only educational module: an artificial tutor. It possesses a domain expertise of knowledge and applies a strategy of education to interact with a student to help him to resolve a given problem. This principle of functioning in autonomy of the couple student-tutor can be satisfying until the moment when the system reaches its limits; the presence of a human teacher, even another student becomes then essential. So, these systems can be used as a supplement to the traditional teaching, in a class for example. However, with the evolution of the networks of communication such the Internet and the services associated as the information servers like Web type for example, the teaching and the situations of learning move from the institutional frame to the room of lessons towards the place of residence, the company, etc.

So, it is now necessary to design EIAH which take into account the mobility of the students, as to ensure them an individualized follow-up to respect their rhythm of learning and put in their arrangement the human presence among all the accessible educational resources.

This work is the result of an interdisciplinary meeting between sociologists and didacticiens on one hand and computer science specialists on the other hand. It articulates around the pooling of the skills of two research laboratories of the university of the harbour: the Computer Science Laboratory of Le Havre (LIH), and more particularly the research group ARM (agents and major risk) and the laboratory CIRTAI-NTIC which has experimented some tools of learning and noted their limits. Our contribution, in the field of the distance learning, consists in designing and in realizing a computer system able to introduce the learning and the managing an individualized teaching and follow-up. This article develops the multi-agent multi-layer architecture resulting from the work of the computer science specialists on the systems of decision making for dynamic situations, which is adapted to the conception and to the realization of an "intelligent" virtual tutor also called "teaching agent " in mobile learning.

2 TEACHING AGENT

The learning situation based on computer is thought like a Human-Machine system. Classically it

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consists in examining the relations between different components: teacher, learner, learning object and computer. Sometimes it also includes a reflexion on these relations and the institutional environment. These learning system are focused on content but do not attach importance to the career of acquiring content. These learning systems generally rest on a transmissive model rather than learning model. It often reduces the e-learning to a learning activity sequential organisation. So the interactivity of the learner is limited by using simple navigation based-function with the tool.

The working party NTIC of the CIRTAI (ANNOOT et al. 2004) (BERTIN, 2004) (BERTIN et GRAVÉ, 2004a) (BERTIN et GRAVÉ, 2004b) shows, for the distant learning system, the specific interactions between different components of an ergonomic model based on a constructivist approach (VYGOTSK, 1978). New interactions add to the usually recognized learning interactions (teacher, learner, learning object), because of the introduction of the distance. Furthermore we have to add the necessity of transferring in a virtual environment interaction whose observation in a presential learning have revealed the importance, particularly peers relations, pedagogic tutoring and follow-up.

About this pedagogic tutoring, we enrich our interactionist and ergonomic model (outline 1) by addition of dimensions that allows the development of learner cognitive and metacognitive abilities: this main line research moves towards the conception of "teaching agent". We lean on the concept of teaching agent, described by Philip Hubbard (Hubbard, 1999), (Hubbard, 2000). It is an informatic entity which, by its graphic, its conception and its dynamic and well-timed apparition mode, plays the virtual tutor role.

Together with Hubbard, such an agent has to present certain characteristics:

- A physical presence and a personality,
- An expertise in the reference field,
- An aptitude for individualised learning,
- An ability to initiate learning.

The following outline situates the teaching agent in the distant learning mediatized systems.

By its appearance and its operating mode, the teaching agent is a sort of technological mediation of human presence which might allow different uses:

- Aid in using activities and software;
- Methodological advices for learning better at distance;
- Selective aid (dictionary, encyclopaedia…);
- Aid production and redaction (thesaurus for language for example);
- Supply additional references;
- Watch learning operation in the background (follow-up functions).

At the same time teaching specialist (the pedagogue), expert and tutor (or companion), the teaching agent is receptive at any time, without any evaluative connotation unlike the teacher. "*The pedagogue in classical times was the slave who escorted the children to school, uneducated slave whose main task was to serve as bodyguard but who could also help the learner in his homework, answer*

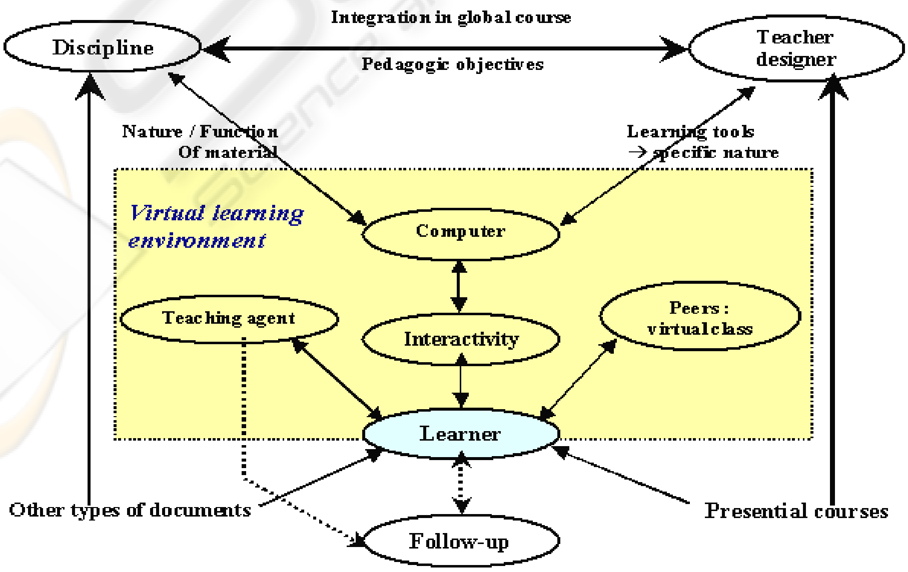

Figure 1: Didactic ergonomic interactionist model (Berlin, 2001, 2004).

questions, play games, or even give tests. But the pedagogue never initiates: he comes forward when summoned and, when the learner has had enough, he goes back to his place. This is the role which seems in some ways a natural one for the computer to assume. After all, computers were built in the first place to answer questions, not to ask them" (HIGGINS, 1986). Its role is essentially formative. This is a less explored domain of research for two main reasons:

- The difficulty to formalize the theoretical nature of a computing agent, capable giving the learner this "cognitive scaffolding" (VIGOTSKI,1978),
- The problems for developing an appropriate technology to these needs. We lean on an experiment, carried out at the University of Le Havre (France), with students in Economics and Social Administration Bachelor's Degree, who received instruction in Organisation Sociology, in two modes: part time in traditional presential learning with the teacher, part time in self-training situation with a CD-ROM. The same contents were given. At the end of the training, students filled a questionnaire about their perceptions of the two pedagogic modes (processing of this data is still in progress). As far as we are concerned, this CD-ROM automatically generates follow-up files, which memorize the student's individual paths. career during it self-training. The analysis of this data files help understand the student's path and examine the pertinence to add a teaching agent or a computing system, that can ensure these pedagogic tutoring functions.

3 OUR APPROACH: DESIGN AND IMPLEMENTATION

3.1 Introduction

There are numerous research works as well as teaching practices coming from the teaching and the computer experiments led in mobile learning and, more particularly, in online training. These works are interested in the conception and the implementation of computer systems allowing to attend the student in his training, BAGHERA (Webber et Pesty, 2002), SIGFAD (Mbala and al, 2003).

The current platforms of e-learning do not have tools allowing to make an individualized follow-up of the student. This follow-up is essential because of the great number of students which do not finish the training. They use a more technical approach, by proceeding to a simple transposition of a traditional pedagogy in a computer portal, than a didactics one, by integrating the contributions of the most recent theories without limiting itself to the structures of behaviourist kind.

In the framework of a self-training, the student must have the freedom and the choice of the course to follow in order to assimilate the object of the learning by a building approach of the knowledge instead of a massive use of documents. This freedom must be assisted by a regular and continuous follow-up. Traditionally, the follow-up is insured by a teacher. The main objective of our training environment, opened and distant (FOAD) is to propose an alternative in the traditional teaching. Consequently, the computer tool has to integrate the assistance and the follow-up among its features.

This expected computer tool is an opened, evolutionary system and a "translation" of the training agent, described in the interaction model of didactic ergonomics according to (Bertin, on 2001) (Figure 1). To meet the needs of didacticiens, it consists in conceiving and realizing a computer system which has to take into account the following characteristics:

Opened: the structure can change dynamically.

Evolutionary: because the components of such a system are not known in advance, change during time, and are essentially heterogeneous.

Autonomous: such a system has to take the role of the teacher and to may be able to initiate the learning.

Adaptive: the system is intended for an individualized learning, so it is needed to take into account the various profiles of the students.

The system is complex. This complexity, which is also translated by the important number of data to be treated and the dynamics of the situation to be treated, led to us to choose the multi-agent systems (MAS) as the modelling (Jennings and al., on 1998).

4 ANALYSING AND DECOMPOSITION OF THE NEEDED

4.1 Introduction

We are making closer the questioning on the analysis of the career of the students in self-training, and the decision system support which have to allow to represent, to follow and to analyze the evolution of a dynamic situation. Such a system allows to represent the observed situation but also its evaluation.

Evaluating the situation can be performed by calculating its possible consequences. This can be carried out using previous situations whose consequences are known. So, a reasoning based on analogy can be used relying on the following hypothesis: **if a A situation looks like a B situation, the consequences of the A situation ought to be similar to those of the B situation**.

The Case Based Reasoning (CBR) (Kolodner, 1993) is a methodology of resolution of problems leaning on the re-use of the experiences spent to resolve new problems. The decision making system is one of the most promising domains of application of the CBR. It allows to put in synergy the capacity of resolution of problem of the man with the capacity of the computer system. Memory of the one and the other one strengthen mutually to participate in the resolution of the problem.

In the framework of a mobile self training offering the individualized follow-up of students, a decision making system, allows to analyze the course and the work of learning it to anticipate a possible finishing of learning it or a "bad" learning of this one.

The system which we propose, has to take into account moreover, the evolutionary character and the dynamics of the course to be analyzed. The analysis is supported by the link which the system is going to make, in a continuous way, between the way of learning it and the past career .

The past tracks are described by scenarios grouped together in a base called "base of scenarios". They characterize, for every past career , all the determining aspects in its progress. We call here determining aspect, a fact which played a current role in the career the events have taken place. So, every scenario contains a temporal list of semantic features associated to the important aspects of the careers.

The analysis of the career s has to be made in a continuous career , in which we must use a multi-agent architecture allowing the implementation of a dynamic and incremental case reasoning for the situations evaluation. This architecture allows the real-time comparison of the situation observed with past situations stored in a base of case.

4.2 Existing Works

In parallel, in this collaboration between computer specialists and didacticiens, the areas of research of the computer specialists of the LIH working on the distance learning, concern the systems of decision making that must estimate a dynamic situation.

Numerous applications of computer systems must allow to represent an evolving situation in order to be able to analyse it. This problem exists in different application domains such as road traffic, meteorology, risks management, etc. The implementation of these systems requires to answer to the following questions:

Which tools to model the situation?
Which tools to model and manage time?
Which architecture to manage the monitoring of the evolution of the situation?
How to allow the users to have a clear and understandable view of the state of the situation and of its possible evolution?

The observed situation generally contains a great number of dynamic parameters, that is to say parameters whose value change over time. Systems allowing the management of such situations must be dynamic in order to be able to handle these evolutions. As a consequence, to design these systems, a flexible and adaptive architecture is needed. This led us to choose a multi-agent architecture(Jennings and al ., on 1998). We are thus interested in the development of multi-agent systems dedicated to the modelization and the evolution forecast of dynamic situations.

Such a system must not only allow to represent the observed situation, but also has to allow its evaluation. Evaluating the situation can be performed by calculating its possible consequences. This can be carried out using previous situations whose consequences are known. So, a reasoning based on analogy can be used relying on the following hypothesis: if a A situation looks like a B situation, the consequences of the A situation ought to be similar to those of the B situation. To perform such a reasoning, we must elaborate:

- a multi-agent CBR. The representation of the current situation is, in our context, based on a set of agents.
- a dynamic CBR. The target case of the CBR process is an evolving situation, so the CBR has to take this evolution into account incrementally. In other words, when the situation changes, it must not be considered as a new target case.

Using such a dynamic multi-agent CBR, the aim of the system is to select as soon as possible the cases of the base which seem to be the most similar

to the current situation in order to be able to anticipate its consequences. Of course, this selection must adapted to the evolution of the situation over time. Indeed, new information on the situation can eventually modify the set of cases which have been selected during the previous steps.
In the following figure (see figure 2), we present a synthesis of the similarities and differences between our approach and the CBR for dynamic situations. More information can be found in (Simon and Boukachour, 2004).

Standard CBR	dynamique CBR	Our approach
Target Case = set of attributes	Target Case= temporal description	Target Case = temporal description
Static elaboration	Static elaboration	continuous and multi-agent elaboration step
Indexation	None	None
Static recall step	Static recall step	Multi-agent and continuous recall step
Adaptation	Adaptation	make by expert
Learnning	Learnning	Learnning

Figure 2: Similarities and differences between our approach and the CBR for dynamic situations.

5 OUR PROPOSAL: PRINCIPLES AND IMPLEMENTATION

5.1 Principles: The Different Kinds of Agents Used

Our architecture is based on a multi-agent architecture as proposed by Marcenac in (Marcenac, 1997). This kind of architecture uses several hierarchical agent layers, a layer of the level n having a view on the layer of the level n-1. Our system use three different layers (see figure 3) :

the lowest one : it contains the agents allowing to model the current state of the situation, that is to say the informational agents,
the intermediate one : it contains synthesis agents used to analyse the previous layer,
the highest one : it contains prediction agents which must provide information about the potential evolution of the situation using dynamic CBR techniques.

5.2 Factuals Agents

First of all, the observed situation is modelled by a set of "factuals" agents. This set of agents receives pieces of information about the situation which are sent to the system by actors or by distributed data bases. Each factual agent is supposed to represent one of these pieces of information which is called "*semantic features (SF)*" (Jackendoff, 1993) (Denhière and Baudet, 1992).. A SF is a three-part-relation <object, qualification, value> representing a partial aspect of the situation. A SF is also the atomic data structure, i.e. the smallest piece of information the system could deal with. (for more details, see (Person and al., 2005) (Boukachour and al., 2002). The main advantage to use agents to represent information about the current situation is that it allows to obtain a flexible representation which can be easily adapted as the situation evolves (ie as new pieces of information about the situation are introduced in the system). Each agent must also provide a temporal validity measure allowing to evaluate the "freshness" of the piece of information associated to its semantic features.

Each informational agent must provide numerical measures of its evolution over time. More precisely, these measures must allow to evaluate the level of reinforcement of the agent inside the organisation it belongs to. Indeed, it is supposed that the more an agent is reinforced, the more its semantic features must be taken into account in the evaluation of the situation. This reinforcement must be based on a similarity measure between items which can use semantic, temporal and spatial aspects (Pesron and al., 2005). These mechanisms allow to take into account the fact that, for example, a piece of information introduced very early in the system can turn out to be non relevant later. On the contrary, some can be given later to the system and finally be judged as very representative of the current state of the situation. More information can be found in (Person and al., 2005).

5.3 Synthesis Agents

The goal of these agents is to provide a synthetic view of the global behaviour of the factuals agents layer in order to facilitate the comparison with past situations stored in the scenarios base. This layer helps to implement the standard target case elaboration step of the case-based reasoning cycle. This elaboration is, however, specific because of its dynamic property.

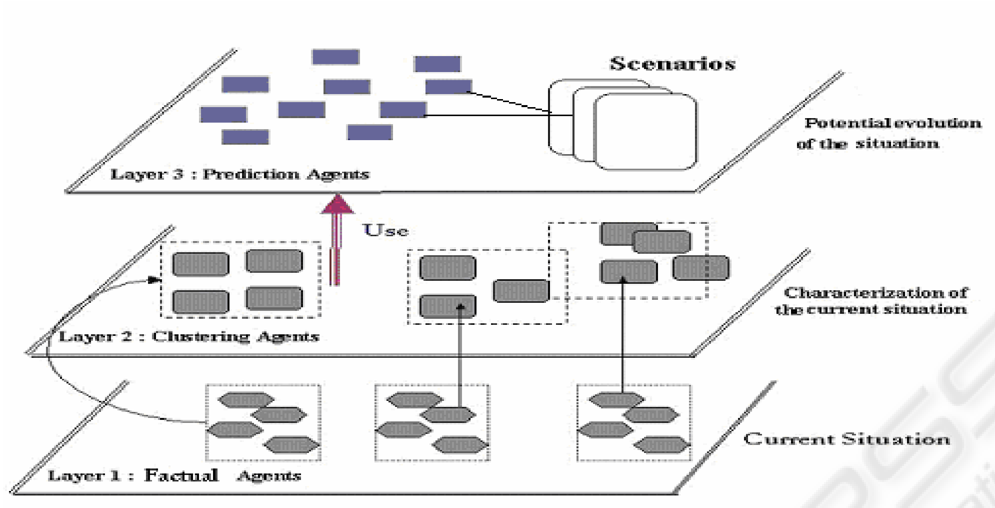

Figure 3: Multi-agent and multi layer architecture.

More precisely, the goal is to classify factuals agents into groups. This operation can be done using reinforcement and temporal validity measures provided by factuals agents. Indeed, if one consider a particular factual agent, the values of its measures are not very significant. On the contrary, if these measures are compared with those of the other factuals agents, it allows to build groups of agents with similar measures values. Theses groups can be representative of important aspects of the current situation which will be used by prediction agents to manage the comparison with past situations.

The goal of synthesis agents is to dynamically build these groups called clusters. In (Coma and al., 2003), we propose a dynamic techniques for agents clustering. Each cluster is modified over time according to factuals agents evolution. For example, it can increase if new informational agents seem to be similar (from the measures point of view) to those belonging to it. On the contrary, it can decrease, or even disappear, if too few factuals agents belong to it.

5.4 Prediction Agents

In order to be able to use CBR techniques, the system must contain cases describing past situations. Such cases are called "scenarios". These scenarios must allow to characterize, for each past situation, the set of decisive factors which seem to be related to the career the situation went on. As a consequence, each scenario contains a list of semantic features associated to the decisive factors of the past situation. This list can, eventually, be organized temporally. These factors can be found using experience feedback provided by domain experts.

A prediction agent is associated to each scenario stored in the system. The goal of the prediction agent is to compare the course of the current situation represented by the factuals agents with the one described in the scenario. This comparison, which must be made in real time, consists in determining if the factors which seem to be important in the current situation are similar to the decisive factors of the situation described in the scenario. In order to do that, the prediction agent must know the factors, that is to say the items associated to them, which are considered to be the most representative of the current state of the situation. Calculating these factors is the job of the synthesis agents belonging to the intermediate agents layer of the system.

The goal of the prediction agents layer is to provide a continuous recall process of cases of the case base, unlike the one used in CBR for dynamic situations described before. Notice that, for the moment, the adaptation step will be done by domain experts which will be in charge to evaluate if the non matched part of the recognised scenario can be used for the current situation. Indeed, the continuous evolution of the analysed situation may decrease the relevance of the adaptation process result. That's why, after having discussed with experts, it has been chosen to give, to the expert, elements about the main similarities and differences between the scenario and the current situation which he can use in order to manage his own adaptation. More information can be found in (Simon and Boukachour, 2004).

6 MULTI-LAYER MAS GENERICITY AND SPECIFICATION

In the previous section, we have presented the multi-agent architecture allowing the implementation of a dynamic and incremental CBR for the evaluation of the potential evolution of an dynamic observed situation. The architecture is based on two parts:

- a generic part: 3 layers of agents;
- a bound part to the domain: ontology, measure of nearness.

The genericity is one of the objectives of the multi-layer system. The genericity of the system must be understood here as being the separation between a part of the mechanisms considered as being relevant independently from the domain. The generic aspect covers:

- the use of semantic features as atomic granules of information piece: at a given time, the current situation is representable by a collection of semantic features;
- a factual agent takes care of a semantic feature;
- a factual agent arranges several internal indicators which inform its states.

Some aspects of the internal indicators of a factual agent are generic. For example, an evolution of the speed will induce an update of the acceleration independently from the domain.

Automaticaly, the ontology is specific to the domain. The categorization of the semantic features is specific too, as the choice of the valid transitions from the generic automaton, the setting parameter of thresholds and the actions were associated to the transitions.

The collaboration between didacticiens and computer specialists allow a clarification of the concepts and the vocabulary of the common domain. To initiate the learning and to manage an individualized teaching in a multimedia environment supposes to translate the characteristics of the teaching agent into multi-agent system. Hubbard isolates four characteristics of the virtual tutor which we suggest to take into account in the multi-agent system in the following career :

the "physical" presence and the personality of the virtual tutor correspond to an adaptive and intelligent human-machine interface;
the expertise in the field of reference corresponds in the MAS to a knowledge base (base of scenarios and ontology);
the capacity in an individualized teaching corresponds to the implementation of a reasoning by dynamic CBR supported by the architecture in three layers;
the capacity to introduce the learning corresponds to an autonomy of the system and the intrinsic proactivity of its agents.

The low layer of the system, the factual agents, contains agents carrying the semantic features bound to the various actions of student. The career of the student is so represented by a set of agents draw. The ontology of the domain and particularly, the object of the learning, allows to define the semantic features.

The intermediate layer, the synthesis agents, consists in placing the agents or the groups of factual agents in regard each others. This layer participates in the phase of elaboration of the target case of the CBR, by keeping that the striking elements of the career of student.

The highest layer, the prediction agents, its role is to build a continual process and incremental of recall step. At each scenario is associated a prediction agent. The purpose of an agent of prediction is to estimate continuously the degree of similarity between the career of the student and the scenario to which it is associated. A scenario contains the determining facts of a known career as well as the result of the evaluation of this career .

7 CONCLUSION

In this article, we have presented a multi-agent architecture allowing the implementation of a dynamic CBR for the evaluation of the potential evolution of an observed situation. This architecture relies on 3 layers of agents with a pyramidal relation. The lower layer allows to build a representation of the target case, i.e. the current situation. The second layer allows to implement a dynamic elaboration of the target case. Finally, the upper layer implements a dynamic process of source cases recall allowing the search for past situations similar to the current one.

The system bases itself on heterogeneous data. It is a question of going from an exhaustive and factual description of the situation (current work) in a level description knowledge allowing to characterize synthetically this situation. The continuous treatment of the information from the environment allows to suggest to the actors (students and tutors) the possible evolutions of the current situation. For that purpose, we have to formalize the representation of the successful information. To represent the current situation, it is necessary to proceed to the construction of an ontology of the domain to be able to categorize the various semantic features (elementary information).

The experiment of a tool of self-training by the sociologists of the university of Le Havre produce a set of files tracks. These files represent the career s of a student to make a study case. The current work consists in analyzing these files, to build the ontology of the domain and specify the low layer by identifying the semantic features.

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