HELP DESIGN FOR THE METACOGNITIVE GUIDANCE OF THE LEARNER
A Proposition of Computer-Based System

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Abstract: This paper presents the framework and the software system we have built in order to provide metacognitive guidance help in Computer Supported Education. The goal is to assist self-regulation of the learner thanks to a dynamic help system which takes into account in real-time the learner's behavior and his profile. The software system is a multiagent system which captures the learner's behavior, analyse it and define the help. Used currently in the step of conception, the software system will become the learning system by successive learning and enrichment. We present its principles and its operational aspects. The application field of this work is the French certificate "C2i".

1 INTRODUCTION: SELF-REGULATION AND METACOGNITIVE HELPS

We are in the context of learning throughout life supported by Information and Communication Technologies (ICT). Students, workers, retired people are more and more often faced with learning alone, at home or on their workplace. In this context, there is usually no teacher present to monitor and assist them. To meet this need, a lot of learning is given through computer-based learning systems: online tutorials, courses, or more integrated systems (Learning Management Systems, Learning and Content Management Systems). In this way, learners have spatial (through remote systems) and temporal (the learners can learn according to their availability) autonomy. If they are properly designed, these systems allow education adapted to the profile of the learner: his knowledge, learning experience, metacognitive profile.

Unfortunately, it is now clear that these systems do not often achieve their goal (Osman and Hannafin, 1992; Winne and Stockley, 1998). One of the problems of the effective use of ICT for learning is that these systems require that the learners regulate their own learning (Avezedo, 2005). Few of them have the required skills for taking in charge ones cognitive functioning (e.g. Hannafin & Land, 1997). Acquiring new knowledge and ability appeals not only to cognitive processes (activation of knowledge, use of adapted learning strategies, and memorization of new knowledge) but also to metacognitive processes (planning, self-evaluation, learning regulation). In face to face education, some of these metacognitive activities are provided by the teacher; in the context of computer supported education, they fall to the learner. It is why we speak about self-regulated learning for this kind of learning.

To help learners to regulate themselves, the designers of computer-based learning systems have added learning helps to support planning, self-evaluation and learning regulation. The table 1 gives some examples of help available on computer-based learning systems; we can see what may be provided by the teacher (in face to face education) and what is left to the learner in the context of computer supported education.

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Table 1: Examples of helps.

Metacognitive activity	Help provided by the teacher (in face to face education)	Help available in computer-based learning systems
Planning	The teacher defines the purposes and the duration of the lesson. The teacher defines the distribution of learning activity.	The system asks the learner to define a priori his learning time.
Self-evaluation	The teacher defines exercises or questions to verify the control of a concept or a part of the lesson. The learner can ask questions to the teacher or to other learners.	The system provides exercises, questions and feedback. The learner can ask questions to the teacher or to others learners via the forum.
Regulation	If the learner meets with difficulties, the teacher can provide help (for example, an explanation in a scheme-form), an advice ("read again a chapter"), an indication ("look for the definition of a concept"), an answer (a solution). The learner can approach other learners.	Depending on the answers to questions, the system may propose to the learner to revise a concept. The learner can approach other learners via the forum.

However, the efficiency of these learning helps has not been really evaluated and some recent works show difficulties in their use. We can notice that some of them are underused or even unused (Narciss, Proske, Körndle, 2007; Narciss, Körndle, Dupeyrat, 2002). Other works highlight inadequate use of help; it is what Roll et al. call metacognitive bugs (Roll et al., 2005): for example, unorganized over-use of help (Roll et al.,2005), exclusive use of help that provides an answer rather than an indication to look for the answer (Aleven et al., 2003).

This rather disappointing acknowledgement raises questions about the metacognitive abilities which are necessary for adequate use of help: to be aware of needing help, to choose an appropriate type of help, to detect the usefulness of help, to realize when help is necessary, and, after failing, to detect which help to revise (Aleven and al., 2003 ; Puustinen, 1998). Works in metacognition field show clearly the difficulties to acquire and to apply such metacognitive abilities, even in face to face education. They show also that these skills change according to factors like learner's knowledge and age.

2 THE CEAGMATIC PROJECT

2.1 An Original Project

Our work is a part of the CEAGMATIC project of the French National Research Agency (ANR). Researchers involved in this project are members of the CLLE-LTC (Laboratoire Travail et Cognition) and IRIT (Institut de Recherche en Informatique de Toulouse)laboratories.

The main goal of this project is to design and build a help guidance system to improve learners' metacognitive abilities. This system has to analyze the learner's profile and to react in real time to learner's behavior. The project team is composed of researchers in the fields of cognitive psychology and computer science.

To the best of our knowledge, only one research center has made such a system (the Human Computer Interaction Institute of Carnegie Mellon University, Roll et al., 2005) but with only one kind of metacognitive guidance. Our system will go further by proposing and comparing many kinds of guidance: one proposed and then accepted by the learner and another one, imposed by the system (in order to compensate for a learner's metacognitive lack or inappropriate behavior).

Another important part of this project is the learners' profiling. We take into account learners' demographics, cognitive and metacognitive profiles: the system will build a learner profile through questionnaires and real time activity analysis. This profile will be used in order to select how and when to help and to guide the learner. It will evolve according to the effectiveness of the helps and guidance. This designing choice allows us to target heterogeneous categories of learners (workers, students, …) as we can adapt the system's help and action to the learner's profile without overloading him with useless interactions and documents.

Moreover, we can provide the help progressively, when the learner (in fact, his profile) evolves.

2.2 The Project's Steps

The project begun on 2007 and will end on 2011. In order to design and build the help and guidance system, we have defined the following steps:

- Preliminary: Defining learner's regular and inappropriate behaviors by analyzing learners' behaviors on provided interactive lessons and exercises (the first version of the system does not provide specific helps) ; this step is completed
- Providing Cognitive Helps: Adding helps devoted to "inappropriate behaviors" identified during the previous step. Then analyzing again learner's regular and inappropriate behaviors integrating these new helps (we will target bad use of these helps as the "metacognitive" inappropriate or missing behaviors) ; this step is in progress
- Providing Metacognitive Helps: Adding metacognitive guidance actions devoted to metacognitive needs identified in the previous step. These actions will be either guidance actions or metacognitive profiling actions.

In order to support these 3 steps, we have built a multi-agent system which can capture and analyze learners' behavior while they study. This system has to provide the lessons and exercises to the learners (Figure 1). The main goal of this paper is to describe and explain how and why we are building this system. The other results of our experiments will be presented later after step 3 will be finished.

2.2.1 Step 1: Preliminary

- A psychologist has studied and analyzed learners' behaviors during face to face lessons
- Experienced teachers have specified the learning activity and the optimal behavior in terms of tasks and knowledge (Paquette and al. 2002)
- e-Learning engineers have built an online course according to the previous specifications
- The online course has been tested over 100 learners and the multi-agent system has recorded all the learners' behaviors into activity graphs (Figure 2)
- Psychologists are analyzing the activity graphs of each learner in order to identify the characteristic behaviors e.g. the learners' regular and inappropriate (mistakes) behaviors while doing exercises.

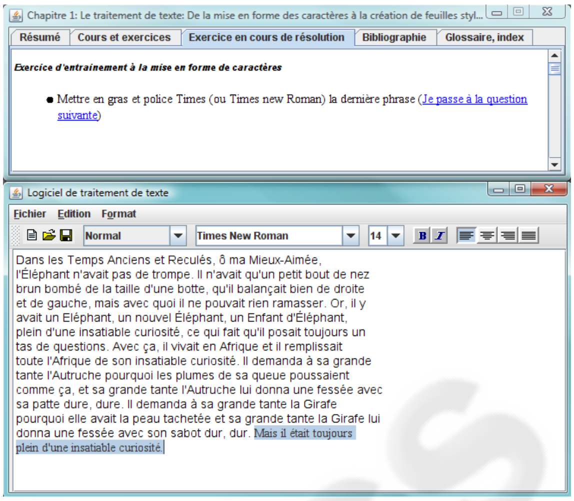

Figure 1: User interface of the multiagent system.

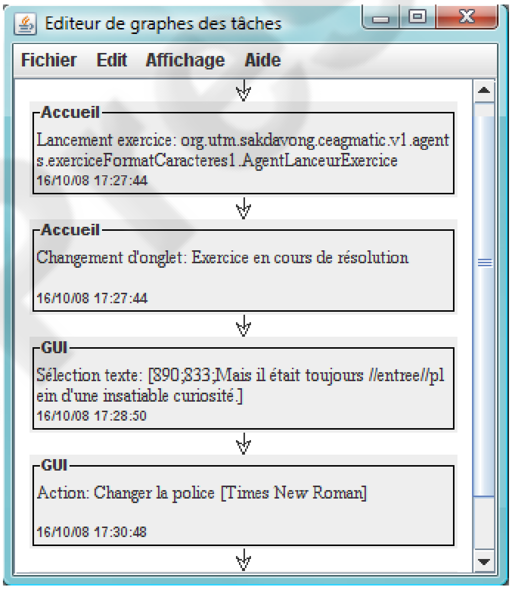

Figure 2: Activity graph recorded by the system.

2.2.2 Step 2: Providing Cognitive Helps

This step consists in conceiving actions associated with each characteristic behavior identified during the step 1. These actions will help the learner when he makes "cognitive mistakes".

- The cognitive helps will be designed by psychologists
- These helps will be included in the multi-agent system as helper agents

- The online course including helps will be tested over many groups of learners and the multi-agent system will again record all the learners' behaviors into graphs
- Psychologists will analyze these activity graphs in order to identify the characteristic behaviors while using the new helps e.g. the learners' regular and inappropriate regulation actions while doing exercises (for example, a learner who never accepts to read again the lesson when the helper agents propose to do it).

2.2.3 Step 3: Providing Metacognitive Helps

This step consists in conceiving metacognitive guidance actions associated with each characteristic behavior identified during the step 2 e.g. bad use of helps. These actions can be assistances but also refinements of learners' metacognitive profiles. Thus, the system will progressively build precise profiles.

We speak here of "metacognitive guidance" because our hypothesis is that if learners do not use correctly the helps, it is because they have a lack of metacognitive abilities: they do not regulate correctly their learning behavior.

Two types of metacognitive guidance will be proposed:

- A suggested guidance that the learner can accept or refuse (Noury and al., 2006), (for example, "you should look at the glossary"; "You should do the exercises before doing the test")
- An imposed guidance if the system identifies a recurrent metacognitive mistake or lack. (for example, a definition from the glossary is presented to the learner)

This is the principal specificity of our approach from the point of view of psychology.

Then:

- The two types of metacognitive guidance will be included in the multi-agent system as new helping agents
- The online course including guidance will be tested over many groups of learners and the multi-agent system will again record all the learners' behavior into graphs
- Psychologists will analyze the graphs of learners' behaviors in order to check if the metacognitive helps are useful.

2.4 Experiment: The Chosen Target Learners

- To experiment, we have chosen the French certificate "C2i (level 1)" (Computer Science and Internet Certificate). The learners have different backgrounds, levels of study and ages.
- Moreover, we have a large population of students for testing and teachers experienced in this training (in the universities of the two involved research laboratories).
- After having analyzed the results over the tests of C2i, we have chosen to target the "Formatting documents with style sheets" lesson. Indeed, this lesson presents cognitive and metacognitive difficulties which can be supported by the help guidance system.

3 DESIGN PRINCIPLES OF THE COMPUTER-BASED SYSTEM

3.1 Dynamics, Flexibility and Scalability of the System

Our system is based on the observation and analysis of the learner's behavior. So, it is based on a dynamic component (the activity) from which the help is constructed dynamically (by observation and analysis). Therefore, the system has to be able to observe, analyze the learner's behavior and to construct real-time help.

Moreover, we propose a general help principle which can be used in any learning situation. Therefore, the system has to be easily adapted, keeping the generic functions of the system, just modifying the learning situation. For example, in the experimentation, it is used for the learning situation : "Formatting documents with style sheets". It should be used for other learning situations like "Using of table of contents or index" or, beyond word processing, like "Using functions in spreadsheet".

Finally, while the system is currently used as a workshop which allows psychologists to observe the learners' behaviors, it will be able (in the third step) to integrate into a dynamic whole the observation-analysis-help process.

3.2 Bootstrap, Grading and Regulation of the System

To analyze the learner's behavior, we use the description of the regular activity and of the possible deviations which are linked to the knowledge and the ability of the current exercise. For example, "Formatting a paragraph" is linked to paragraph and alignment concepts (knowledge), and to the designation of a paragraph and of an alignment (ability). The regular activity and the possible deviations compose the system's bootstrap.

They are completed and refined during the analysis of the activity by the psychologists. This analysis allows also designing the action system: an action (cognitive profile modification, help suggestion) is associated with each characteristic behavior. It is what we call the grading of the system.

Finally, the regulation of the system consists in adapting the help as the system runs. Ideally, it should be a self-regulation of the system. But for the project, we will allow only a dynamic regulation within the action system defined by the psychologists in the second step.

3.3 Functional Aspects

Our help system is based on the observation and analysis of the learner's behavior. Therefore, it is necessary that it places the learner in a position to do and can observe his actions. It is why the system has to integrate learning interactive tools. For example, we have integrated a text editor for the experimentation.

To analyze the activity, we have integrated a tool which allows the observation of the learner's behavior. We wondered about the granularity of the observed actions. Technically, it was possible to observe elementary actions (click, mouse moved, …). But, after a first test, we realized that the important actions were:

- Actions on interactive objects ; for example, a selection in a menu or the validation of a dialog box
- Semantic actions linked to the learning context; for example, putting a word in italics

Therefore, the system observes and records these actions which are analyzed by the psychologists, observed and then processed by the system to generate the help in the next step.

The psychologists analyze the learner's behavior in relation to the regular activity. To make the analysis of the activity easier, we have integrated tools to describe the regular activity and to represent the observed one with the same graphic formalism; these tools can also represent the differences between regular and observed activities.

Finally, the system contains a tool of automatic analysis of the activity which allows detecting characteristic behaviors, and an action system able to activate help and to modify the profile.

All these functional aspects have been integrated to the computer system.

4 SOFTWARE ARCHITECTURE OF THE MULTI-AGENT SYSTEM

4.1 Why a Multi-Agent System?

We have implemented the device to deliver online course and to provide helps as a multi-agent system (Wooldridge, 2002). This choice of implementation allows us:

- To have software elements (agents) able intrinsically to observe the activity and to produce a behavior, also to communicate between them;
- To obtain a dynamic behavior of the device, creating agents during the learner's behavior (for example, creating a new helping agent when an exercise starts) or modifying in real time the behavior of agents (for example, an helping agent can change of behavior according to an evolution of the learner's profile);
- An incremental construction of the device;
- A flexible and dynamic construction of the device; for example, we can replace the agent "text editor" by an agent "spreadsheet" according to the situation of training, without modifying the remainder of the device;
- To consider a distributed runtime of the various elements of the device on various computers (the learners' computers, the LMS's computers and the learners profiler computer).

We have used the framework JADE (Bellefemine, F. and al., 2004) and programmed the agents in the Java language.

4.2 Agents of the System

The system is composed by several types of agents:

- "Principal", "Exercise" and "Applicative" agents which constitute the LMS (Learning Management System);
- An "Historical" agent;

- ”Helper”, “Scrutinizing” and “Profile” agents which constitute the system of analysis and the system of help.

The LMS includes a “Principal” agent which implements the teaching scenario. The figure 1 shows the human-computer interface of the LMS: the summary (“Résumé”), the course and the exercises (“Cours et exercices”), the self-assessment (“Autoévaluations”), the external references (“Références”), the glossary and the index “(“Glossaire, index)”. When the learner chooses an exercise, the “Principal” agent creates an “Exercise” agent implementing the scenario of the corresponding exercise; we can have thus simultaneously several “Exercise” agents An “Exercise” agent is always associated to an “Applicative” agent which implements the interactive system necessary to the realization of the exercise; in the current project, this agent implements a word processor.

The “Historical” agent records the learner’s behavior as a sequence of actions (the activity graph). It thus communicates with the previous agents: it records the activity with respect to the full teaching scenario (for example, it records if the learner consults the exercises, then reaches the course), to the scenario for a particular exercise (for example, when the learner answers the first question, then the second one, then returns to the first one), to the “Applicative” agent (for example, the learner selects a paragraph then clicks on the shortcut button “centering the paragraph”).

“Scrutinizing” agents allow observing and analyzing the activity of learning. These agents are charged to identify characteristic behaviors, according to the profile. They are created dynamically by the “Exercise” agents. They have a mechanism of subscription which enables them to receive from the “Historical” agent the sequences of actions they are charged to analyze. According to their analysis, they will create “Helper” agents or will communicate with the existing “Helper” agents. They will also communicate with the “Profile” agent charged to dynamically adapt the profile of the learner.

The “Helper” agents provide the assistance by giving feedback, displaying solution, procedure, chapter corresponding to the difficulty, asking questions to the learners. In the last step of the project, they will give the metacognitive guidance to the learners. They also will communicate with the “Profile” agent.

5 CONCLUSIONS

We have presented the process and the software device that we have developed, associated to the design of a new kind of help. The multiagent architecture used to implement the software system is an original way to deal with the complex problem of a dynamic and contextual learning help. It allows to meet the dynamic, flexibility and scalability requirements of the device.

We are testing it with the learning of the C2i certificate. At present, we have realized the first step of the process (we have defined the regular behavior and the possible deviations) and constituted the bootstrap of the software device. Then we have recorded the behavior of a troop of learners with the software device. Currently, a psychologist is analysing these recordings (step 2 of the process). Afterwards, the results of this analysis will be integrated into the system and will be evaluated.

At the same time, we are working on the specification of « Helper » agents to add syntactic analysis abilities to them: each « Helper » agent will be defined by an abstract grammar which will be specific to a learning behavior. Then, the psychologists would just have to define abstract grammars and associated semantic actions.

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