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ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 6 (8): 1199-1207, 2007
ISSN 1812-5638

Agent-Based Virtual Assistant in an Interactive Learning Environment

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Abstract: The most commonly used models, for distance training environment, propose learning activities which are generally limited to online lessons consultation and submission of home works to be marked by Graders before they are sent back to the learner. The tutors, seldom, intervene at the time when the learner is in the process of performing his/her learning activities. We present in this paper the design of an agent based interactive environment to assist the learner. This environment offers to the learner self-training resources, tutor service and distance assistance. In this context, the assistant can play the role of a substitute teacher and companion to the learner. We propose the use of an agent-based approach, which is a suitable for two main reasons: agents are a natural metaphor of human and it is convenient for complex distributed systems. Therefore, our aim is to create a personalised artificial assistant agent who is able to communicate with learner and help him/her to perform the tasks. The MaSE (Multi-agent Systems Engineering) methodology is used to develop this system.

Key words: Artificial assistant agent, agent-based design, MaSE, interactive learning environment

INTRODUCTION

The improvement of distant access, the increase of the organisational constraints that require the installation and the management of complicated training structures, as well as the lack of human and financial resources have pushed people to think about innovative training methods. These methods integrate in different ways the Information and Communication Technologies (ICT) in the designation of New Educational Technologies. The appropriate use of the web-based learning has the potential to enhance both learning effectiveness and teaching efficiency (Chau, 2007).

Unfortunately, the most commonly used models, for distance training environment; propose learning activities which are generally limited to online lessons consultation and submission of home works to be marked by Graders before they are sent back to the learners. The tutors, seldom, intervene during the time when the learner is in the process of performing learning activities because they are not available. However, because the learner is autonomous and is isolated sociologically within a distance learning environment, he/she needs usually synchronous support.

The works done on Interactive Learning Environment (ILE) for human which is related to research in informatics are works associated with the design and conception of software taking into account the objectives and constraints related to a training which, presents problems that are complex to the point that they can not handle by an engineer. The complexity of distance learning platform forces us to divide the implementation into small intelligent entities that act in the environment and interact to produce an intelligent system. These intelligent entities are called artificial agents.

GOALS AND APPROACH

Approach objectives: We aim to develop an agent based digital work environment able to take into account the problems encountered by the different forms of distance learning, namely: the learner sociological isolation, the loss of motivation and the autonomy of the learner. So we are interested, to remotely follow-up the activity. In particular we want to take into account the personalization dimension by the tutor. This environment has to:

- Provide the necessary tools to make a learner, working from a distance, feels the same way as if he/she working face to face, while allowing more flexibility with the respect to time and space constraints.
- Propose tools to follow up, help the learner and evaluate his/her work.

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In this digital environment of agents of various species human and artificial, of different levels, having different expertises and different objectives must interact.

Didactic choice: In order to imitate a face to face teaching situation, we did a sample survey with 112 students and 20 teachers at the University of Setif (Algeria). This survey collected, among other thing, data concerning the teaching methods deployed by the teachers or desired by learners and their opinions concerning certain training scenarios.

The information about exercise explanation typologies, due to a request by the learner, to an erroneous answer or to the expiry of the allocated response time, relates to the following 5 models: Direct the teacher gives the correct answer directly, Maieutic sequence of questions/answers, Partial when learner is blocked, help him/her partially, Analogy to explain with a similar example, Lesson to advise the learner to review the lectures.

Information about the suggested courses is collected according to the explanation model: Lecture, Debate, Maieutic, or Analogy. Other information collected is concerned with the exercises' types, the effect of the tasks assigned to the teacher on his/her performance and the importance of the teacher availability to the learner.

The proposed survey contains multiple choices. The collected results, therefore, are reported based on the number of answers and not on the number of questioned.

The results of the investigation (Table 1), concerning exercise and lessons explanation methodologies, show a clear preference of two methodologies Maieutic and Analogy with a slight preference of the Maieutic with 37% of the learners and 29% of the teachers for the exercise explanation and 43% of the learners and 28% of the teachers choosing this method for the lesson explanation, for the other choices the results remained mitigated and equivalent.

As for the exercises types, the Applications type of exercise is chosen first, followed by the Problems in second position and finally the MCQs (Multiple-Choice questionnaire).

More than 82% of the learners think that it is important to have a teacher available, to motivate them, to follow up their work, to help them instantaneously when they are stuck and to encourage them.

Fifty percent of the teachers, who answered the survey, think that the teacher performance depends on certain factors, such as: the responsibilities which are assigned to him/her, the work load, time, the availability and tiredness. The other half believes that there is no relationship between the teacher performance and the load assigned to him/her.

Table 1: Synoptic table of the sample survey

Analyse	Actor	Learners	Teachers
Exercise explanation methodologies	Maieutic	47	14
	Analogy	42	10
	Direct	15	06
	Lesson	13	10
	Partial	09	08
Exercises kinds	Application	65	16
	Problem	53	16
	MCQs	25	02
Lecture explanation methodologies	Maieutic	57	10
	Analogy	45	08
	Masterly	17	10
	Debate	13	08
Teacher availability	Yes	85	/
	No	27	/
Availability → motivation	Yes	92	/
	No	20	/
Output/Tasks	Yes	/	10
	No	/	10

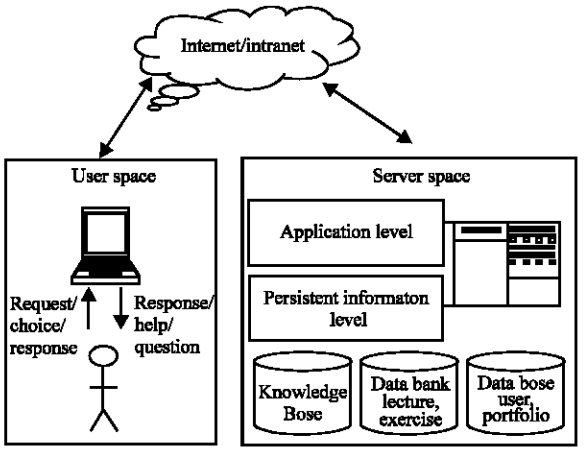

Fig. 1: Environment structure

Environment structure: The acquisition of new knowledge is done within the framework of an interaction between the learner and a human (a teacher, a Co-learner) or a device in which this knowledge is processed (Jhonston, 1997).

The system to be designed should be organized as a network. This network is going to link the devices of different participants (Teachers and Learners) and will support various communication forms. It is divided in three entities (Fig. 1). User space which include the human-computer interface; the application space considered to be the system kernel and storage space where the information should be stored in way too consistent under different structures (Harbouche and Djoudi, 2007).

PEDAGOGIC MODEL

We propose a model, which allows the conception an agent based distance-learning environment shown in

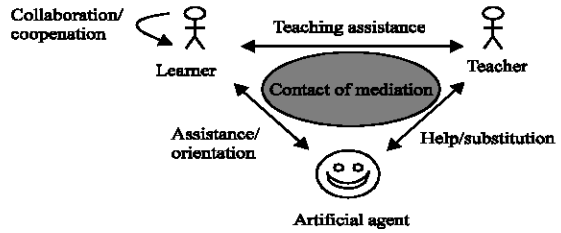

Fig. 2: Pedagogic model

(Fig. 2). We take into account the three main participants who are assigned the same importance: the teacher, the learner and the artificial agent.

The three main participants: The teacher, the tutor, the instructor or the trainer: A human agent, who is in charge, at the same time, of the tutor's tasks who prepares the contents and that of stimulating tutor. He/she must, assist learners by answering their questions, supervise their work historic, work in progress, evolution, grade the exercises that can not be graded automatically by the computer and update the contents of the lectures and/or exercises.

The learner: The learner is the principal actor, who is at the heart of the learning process. He/she is the only one who transforms the information presented to him/her into the appropriate knowledge which is the goal of the learning process. He can exploit the various tools to consult the courses, to solve the exercises and to communicate with the other participants (Faerber, 2002).

The artificial agent: It can substitute for the teacher, help and collaborate with him/her. It can be delegated certain missions or to subcontract a part of the work of the teacher. The agent can, also, assist the learner during exercises solution session, orient him/her and evaluate in real time the exercises which contain multiple choices questions. The artificial agent must give, receive and stimulate the pleasure of learning for a learner left on his/her own.

The context of mediation: An environment is a space representing the world in which the agents move. We distinguish between the agents which are active entities and objects which are passive entities located in the environment. In order to define the human and artificial agents work environment, we have to define the means and/or pedagogic, social, administrative, epistemological resources which are similar or as close as possible to those used in a face to face teaching environment. The context of mediation gathers the various tools required to make the learning a success.

Pedagogic resources the portfolio: The portfolio or the schoolbag is a log journal, a process, a learning approach and an evaluation (Tchounikine, 2002) which helps, learners to learn and to progress (Gerbault and Portine, 2001). It also helps the teacher to take the necessary measures to guide the learner to improve their learning (Muller, 1999). Among, the pedagogic types which make use of the portfolio, we have the cognitivism and constructivism (Goupil, 1998). We find four kinds of electronic portfolios (Harbouche and Djoudi, 2006).

- **Learning portfolio:** Contains tasks accomplished by the learner. This portfolio gives the teacher the opportunity to follow the learner's progress during the learning process.
- **Presentation/communication portfolio:** Contains the productions that the learner likes to keep while writing his/her opinion for other pedagogic participants collaborative learning.
- **Evaluation portfolio:** Contains evaluations and opinions done by the teacher on some chosen tasks accomplished by the learner.
- **Teacher rack:** It is file containing the progressive teachers' evaluations of the learner's work. It also contains their opinions concerning the learner's cognitive capabilities.

Didactic elements: We should distinguish two main approaches in the human learning process: the first one consists in an explicit production of the written representation of knowledge (lecture). The second one consists in constructing knowledge by encapsulation. The learners gain knowledge by solving problems.

- **Lecture:** It is of course an essential element in any training program. The lecture notes can be annotated by the learner, in order to share his/her understanding with the others learners. The teacher may index the lecture notes.
- **Evaluation tools:** They allow better evaluation of the student, who is working alone. We can divide the evaluations into three categories (Perrenoud, 1991): summative evaluation direct examination in face to face, formative evaluation continuous evaluation during the learning process and diagnostic evaluation to have an idea on the learner's cognitive capabilities. These tools are applied in form of small projects and/or various exercises of different levels of difficulty simple, average or high:
  - **The MCQs:** It is the simplest type of exercises. It does not require a human evaluator. This type of exercises are graded automatically by the computer so right after the learner submits the

solution to the exercises, he/she will get graded. We also have: the alternate MCQs where the answer is Yes or No, the elementary MCQs only one answer is correct, the simple MCQs one or more choices are correct and the control MCQs with a percentage of conviction.

- **Traditional exercise problem:** It is the same kind of exercises that we find in a traditional training. The solution is more complex to be analyzed and evaluated in an automated way using a computer. It is necessary in this case to resort to a teacher to grade the solution submitted by the learner.
- **Assisted exercises:** These are traditional exercises but their solution is guided by the system, which proposes hints to the learner throughout the solving process.

AGENT BASED DESIGN

Assistant agent: An agent is widely defined to be a software entity part of an environment. It reacts in an autonomous and a flexible way to achieve the objectives for which it was created (Luck *et al*., 2003).

The Multi Agent Systems MAS are very well suited to the design of our training environment because of the following three characteristics:

- The distance learning systems are open, dynamic and complex.
- gents are a natural metaphor of human participant.
- Data, control and the expertise are distributed by nature.

The agent-based approach is used more and more in the educational field to accelerate the learning process (Subarnıamiam and Emaliana, 2005) and efficiency in managing the voluminous learning material that grows and changes (Pesty and Webber, 2004). It is, already used, in the workflow tools (Levan, 1999) and the Computer Supported Cooperative Learning (CSCL) (Mbala *et al*., 2003).

The personal assistant agent (IPA: Intelligent Personal Assistant) is an agent intended to help us in our daily work. It helps us to complete some tasks or even performs some of these tasks on our behalf. Due to this kind of agent, the computer becomes an intelligent, active and personalized collaborator.

MaSE approach (Multi-agent systems engineering): MaSE uses the abstraction provided by multi-agent systems to help designers develop intelligent, distributed software systems (Deloach and Oyenan, 2006). MaSE considers agents to be an abstraction of the object-oriented paradigm where agents are specialized objects. Instead of simple objects, with methods that can be invoked by other objects, agents coordinate with each other via conversations and act proactively to accomplish individual and system-wide goals. Agents are a convenient abstraction that allows designers to handle intelligent and non intelligent system components equally within the same framework (Deloach *et al*., 2001).

The MaSE methodology consists of two main phases that result in the creation of a set of complementary models: The first phase is the analysis Phase Capturing Goals: Goal Hierarchy model, Applying Use Cases: use Cases and the Sequence Diagrams and Refining Roles: Concurrent Tasks and Role Model. The second phase is the design Phase Creating Agent Classes: Agent Class Diagrams, Constructing Conversations: Conversation Diagrams, Assembling Agent Classes: Agent Diagrams and System Architecture: Deployment Diagrams.

MaSE is an iterative methodology. Its objective is to free the designer to move between different phases in order to add additional detail which, eventually, leads to the design of a complete and consistent system.

SYSTEM DESIGN

System goals and roles: A teacher has multiple and diverse tasks to do. Actually he/she has to follow-up learners and communicates with them in real time. Since he/she can not follow up all the learners and he overloaded with the different tasks to be done, some these tasks can performed by artificial agents as shown in (Fig. 3):

- MCQs automatic grading.
- Help the learner to solve the exercises and guide him/her in case he/she issues a request, the time reserved to think about the solution has finished, or a learner provides an erroneous answer.
- Course explanation using the maieutic method.

Agents have to ensure communication between human agents, protect the system access and manage the persistent information.

In order to identify the functionalities of the system to be designed we will use the usage case diagram. For this, we will use the following generic representation: participant (usage case$_1$, … usage case$_n$) meaning that the participant has access to the system functions described by usage case$_1$ to usage case$_n$.

Based on this simplified notation and with reference to the participants described above, our system posses the following key usage cases:

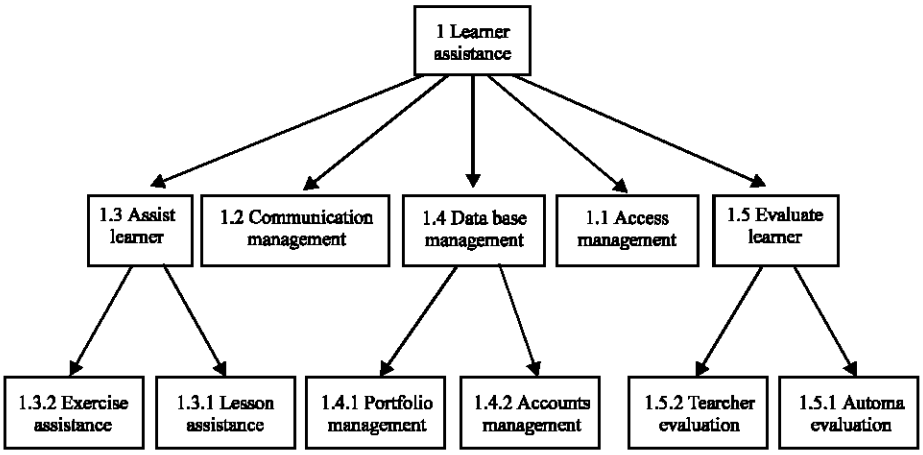

Fig. 3: Goal hierarchy model

- Teacher (assists student, updates training contents, grades exercise's solution, communicates).
- Learner (access to training contents, searches in the index, undertakes applications, communicates, solves exercises, annotates lesson).

The MaSE analysis phase's objective is to define a set of roles that can be used to achieve the system's goals. These roles are defined explicitly via a set of tasks, MaSE is built on the assumption that the system's goals will be satisfied if each goal maps to a role and every role is played by at least one agent class. In general, the mapping of goals to roles involves a one-to-one mapping. However, the developer may choose to allow a role to be responsible for multiple goals for the sake of convenience or efficiency.

Based the preset usage cases and the system's goals we can deduce the following set of roles:

- Learner interface role: Realizes the learner machine interface.
- Teacher interface role: Realizes the teacher machine interface.
- Companion role: Assist the learner during an exercise solving session.
- Learner assistance role: Maieutic explanation of a lesson.
- Evaluator role: Automatic evaluation of exercises.
- Supplier role: Data base management: users' accounts, portfolios and pedagogic contents.
- Communication role: Facilitates and manages the communication between users.

A sample sequence diagram: The interactions between roles are developed using sequence diagrams. The main difference between MaSE sequence diagrams and UML (Unified Modeling Language) is that in MaSE they are used to represent sequences of events between roles instead of objects. The events sent between roles are used in later steps to help define the communications between the agents that will be eventually playing these roles.

A sample of interactions (Fig. 4) during an assisted exercise session: As soon as the learner loads a work on an assisted exercise, the companion's clock will be also started. The companion intervenes in one of the following cases: if the granted thinking period for this exercise is exceeded; if the provided answer is erroneous or at the learner request. Following a correct answer, the companion validates and congratulates the learner. The learner-companion dialogue is maieutic.

System agents: These agents have to communicate among themselves in addition with the users actors, assist learners, help teachers, consider and modify the users Database DB. The result of the role diagram is the following Agents (Fig. 5):

- **Learner interface and teacher interface:** These two agents have to get, announce and return available information relating to the user needs request and choice; response and sending information.
- **The assistant:** It must assist the learner, guide him/her during an assisted solving session of exercises and answer his/her questions directly. It may intervene in a pedagogical way during a guided working session.
- **Communication:** Manage synchronous/ asynchronous communications, between the different participants.

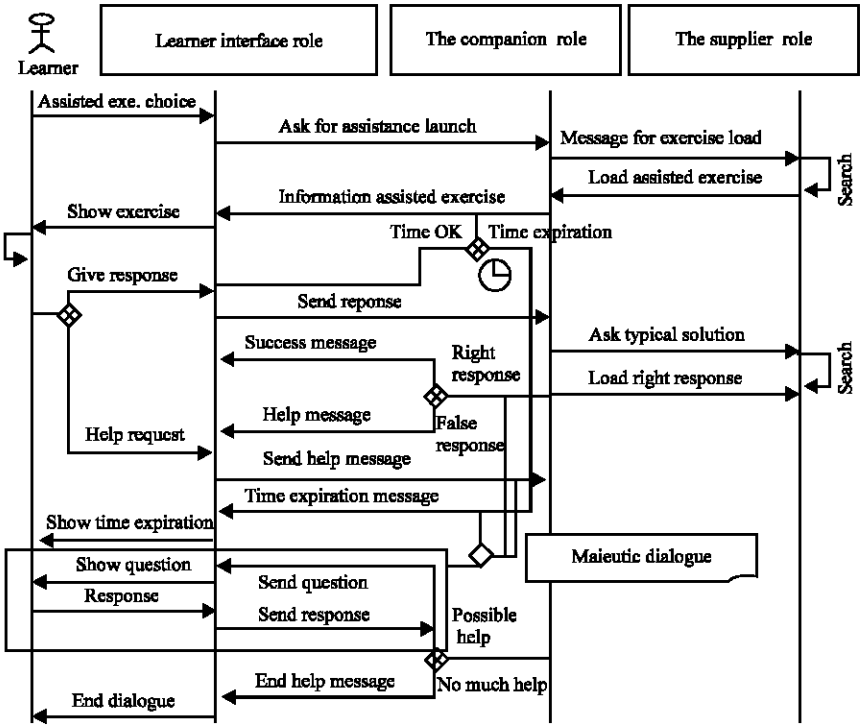

Fig. 4: Sequence diagram

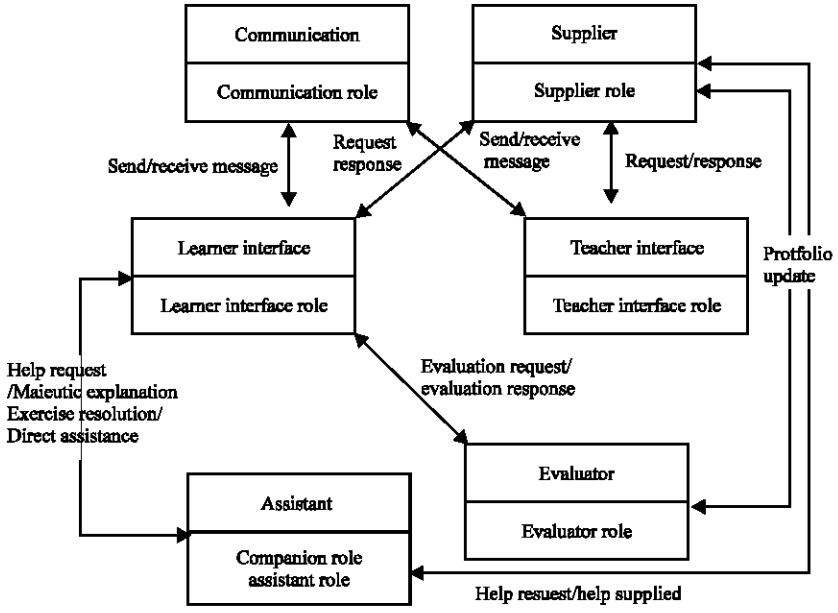

Fig. 5: Agent class diagram

- **Evaluator:** It evaluates MCQs, gives result instantly to the learner and updates the learner's evaluation portfolio.
- **Supplier:** It manages and resolves conflicting access to the persistent information in the Database.

System architecture: The last phase in building a multi-agent system using the MaSE methodology is to decide on the actual configuration of the system. It consists in deciding the number and types of agents in the system and the platforms on which they would be deployed.

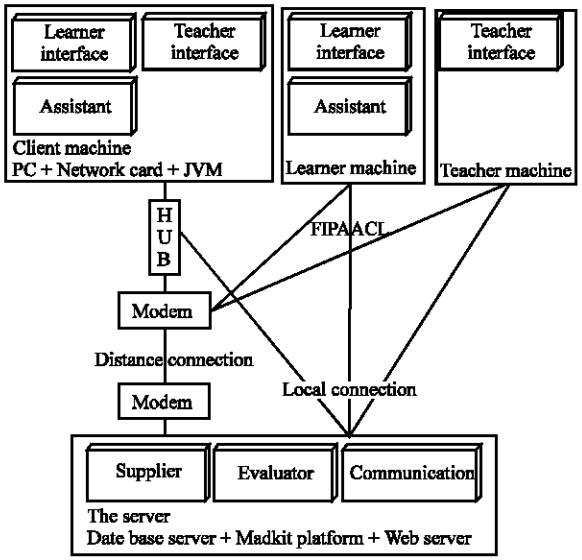

Fig. 6: Deployment diagram

These decisions are documented in a deployment Diagram as (Fig. 6), which is very similar to a UML Deployment Diagram and is used for the same purpose.

The Interface agents migrate on the client machine: each human participant has his/her own agent.

The supplier, assistant, evaluator and communication agents remain on the server machine and are used by several customers.

The MadKit platform (Gutknecht *et al*., 2002) Multi-agents development kit is deployed for the execution of our MAS. The communication between agents is implemented in the form of asynchronous messages passing, either from an agent to other agents identified by their Agent Address or their group and role, or by broadcasting the message to all agents, in a given group, playing a particular role. This communication follows the standard FIPA-ACL Foundation for Intelligent Physical Agents-Agent Communication Language model (Odell, 2007). The following example shows the sending of a message S to the Supplier agent.

The Beliefs Desire Intention (BDI) agents development is made jointly with Jess Java Expert System Shell. Jess is a rule based engine which authorizes, among others, to program Madkit agents (Hill, 2007).

IMPLEMENTATION

Agents' life cycle: The periods during which the agents are present within the system according to the human users (learner, teacher) actions (Fig. 7).

The agent's lifespan in the system differs according to the role played by the agent. The Interface and Supplier

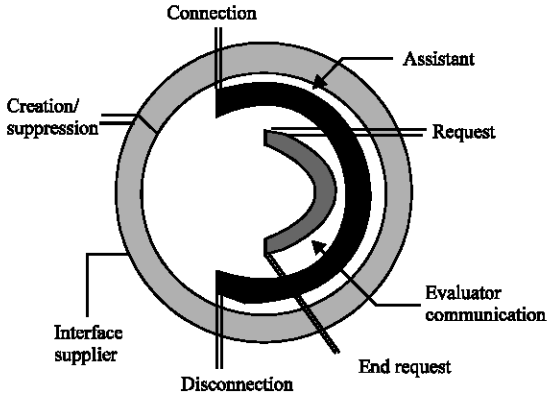

Fig. 7: Agents life cycle

agents are created as soon as the system is launched and are terminated at the end of the execution. On the other hand, the evaluator and communication agents are created following, respectively, an evaluation or a communication request between human agents. Their exit of the system is carried out when they finish the tasks assigned to them. The Assistant agent, is created once the human user is connected successfully after the password validation.

The following function allows the activation of the Supplier agent. A message is displayed after its activation using the Madkit platform:

```
public void activate()
{
    createGroup(true,Tuteur,null,null);
    requestRole(Tuteur,supplier,null);
    println(Supplier agent been activated);
}
```

Sample Interfaces: Screens shown below represent some learner interfaces:

- Assisted exercise solution: The learner can choose the exercise to be solved. A time to think about a solution is allocated. This time is variable according to the exercise type and its degree of complexity. Four spaces are placed at the disposal of the learner (Fig. 8). The first space is used to display the body of the exercise. The second space is intended for the question/answer between the companion and the learner. The third space is used to progressively display the dialogue that happens during the exercise solving session. The fourth space is used to progressively display helps shown to the learner.
- Lecture session: The learner has, here, four spaces (Fig. 9). The first space intended for displaying the

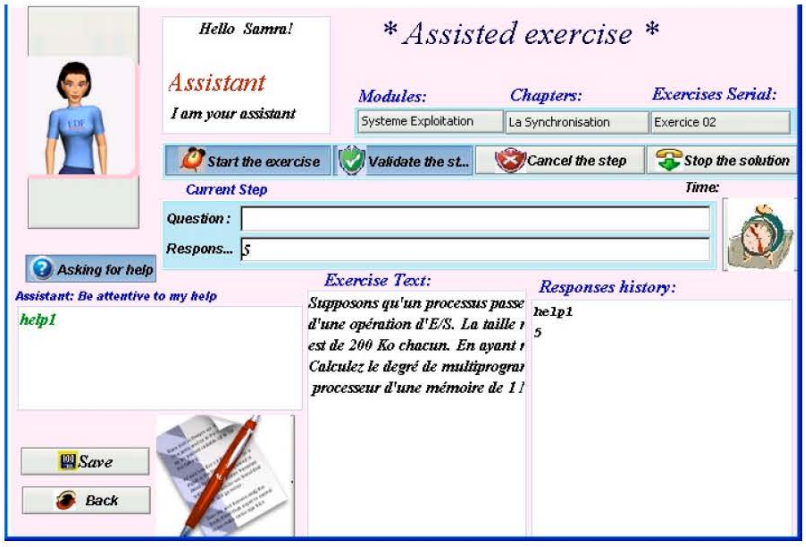

Fig. 8: Assisted exercise resolution

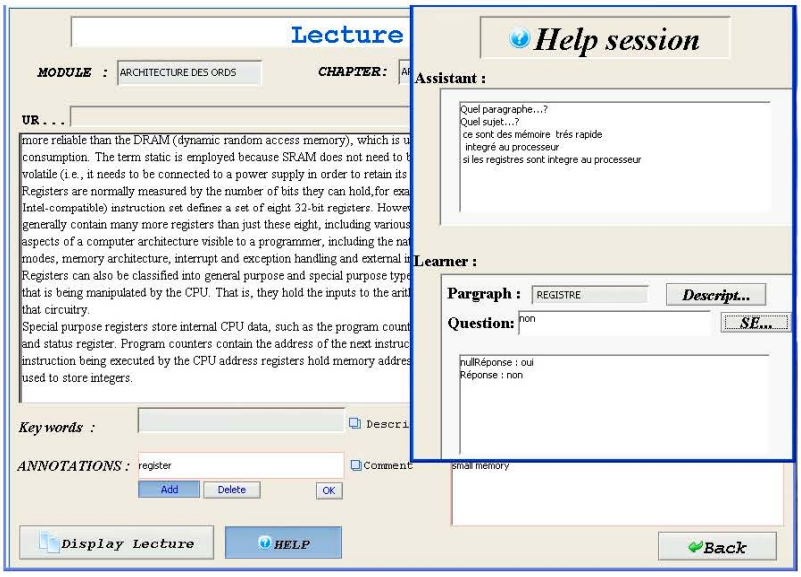

Fig. 9: Lecture session

lesson. The second space shows the indices, allowing the learner to seek the definition of a particular term. The third space is for the annotations. It allows the learner to annotate his course or to import annotations made public by the others learners. The last space is intended for the maieutic dialogue between the learner and the assistant in order to explain the course on request.

CONCLUSIONS

The introduction of technologies is not synonymous with paradigmatic upheaval of previous teaching method but it makes possible to question these models.

We have presented an agent-based design for an assisted learning environment using MaSE methodology. The use of the artificial agents was beneficial and

practical to us considering the system complexity. It allows us to divide the problem into intelligent communicating entities and distributed in space. These entities can substitute the teacher and thus reduce his/her tasks. The artificial agents can, also, assist learners in an asynchronous way during an exercise solving session or a lecture session.

The application of an easy and complete methodology covers the various steps of the analysis and design of the software engineering process such as MaSE has largely helped us in the identification of the agents.

We experimented with our learning system to imitate a face to face teaching situation. 112 students and 20 teachers from the University of Setif (Algeria) participated in this sample survey. We deployed a maieutic explanation method for both the lesson and the assisted exercise.

In the statistical study that we made, we deduced that there was a relation between the level of the learner and his/her choices. In order to improve the work presented in this paper, we intend, among other things, to have recourse to adaptive hypermedia in order to make the pedagogic contents closely related to the cognitive and emotional profile of the learner.

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