# The Baghera project: a multi-agent architecture for human learning

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**Abstract.** The Baghera project intends to develop theoretical and methodological foundations to guide the computer modelling and conception of learning environments. This paper presents the Baghera platform, which is founded on the principle that the educational function of a system is an emerging property of the interactions organised between its components: agents and humans, and not a mere functionality of one of its parts. Our first achievements include a web-based multi-agent architecture for learning environments and an operational prototype for the learning of geometry proof. We start this paper with a brief overview of the project Baghera. Then we describe the multi-agent architecture and the learning environment for geometry proof construction. We conclude by discussing some perspectives for future developments.

## 1 Introduction

For three decades, actually since the very beginning of AI and Education research in the late seventies, the design of educational systems has been based on the principle of teaching a universally valid reference knowledge in a standard way. This principle resulted in a modular architecture composed of three main components: the domain knowledge, the pedagogical expertise and the learner model.

This view did not allow systems to adapt to the quick evolution of knowledge and did not acknowledge the diversity of human culture and rationality. Since Wenger [26] and Olsson's [21] publications about tutoring systems, little progress has been made in this area. Even the attempts to import tools from AI (ontologies, agent technology, and so on) have been made considering the same epistemological basis: looking for a generic model of teaching and/or learning (under the pressure of re-usability) and referring to a static and academic view of the knowledge to be taught.

On the other hand, educational research proposes a large number of local models of learning and teaching, so as models explaining how to look at student's way of knowing. Taking this into account, the Baghera project follows a different approach:

1. The design of educational environments takes the collaboration between human and artificial agents as a foundational principle;

2. The learner's knowings consist of a diversity of conceptions, whose basic criteria of relevance are not their conformity to some knowledge of reference but their efficiency in specific spheres of practice [3];

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3. *Education* is the result of an emergent complex process. It may not be the result of the action of one isolated strategy or the accomplished goal of one isolated agent. In essence we consider that education, as a complex phenomenon, can emerge from interactions among agents having different and complementary abilities [4].

In accordance with these three considerations and from a technological point of view, the Baghera project aims to design, develop and experiment new software architectures for learning environments. In this paper, we introduce the multi-agent architecture of the Baghera platform. Then we present the first prototype for teaching geometry proof. Finally, we conclude with some remarks and perspectives for future developments.

## 2 The multi-agent architecture of Baghera

Web-based technologies in conjunction with multi-agent methodology form a new trend in modelling and development of learning environments. Web-based education has been extensively covered by Brusilovsky, especially in [6], where its benefits to learning were shown. On the other hand, multi-agent methodology has recently appeared as an alternative to conceive distributed learning applications. The main reasons of this are the evolution of multi-agent technology itself and the fact that multi-agent methodology deals well with applications where crucial issues, such as: distance, cooperation among different entities and integration of different components of software, are found.

Several projects implement learning environments based on multi-agent architectures. For the sake of brevity it is not possible to present an extended review about the application of agents in the area. However, we distinguish here different kinds of projects working on multi-agent-based learning environments. Some of them work on a generic platform of agents [9, 19, 24, 25], but usually the focus is given to a specific agent type. Interesting results have been achieved by pedagogical agents [17] regarding the student motivation and companion agents [10] acting sometimes as mediators [11] of the learning process. Finally, tutor agents [22] are usually related to student modelling and didactic decision taking [23].

We have implemented an environment, based on a multi-agent architecture, which provides individualised support for problem solving [5]. The current version of the platform was developed using JatLite [16]. JatLite is a package of programs for creating software agents. Each agent was extended by an interaction module [15], which provides support for managing protocols among agents. Agents have the ability to communicate with other agents, reason and take decisions. Communication among agents is based on the speech act theory in accordance with FIPA-ACL standards [14].

The potential of agents can be reached only by software engineering techniques specifically tailored to them [27]. Following this view, the multi-agent architecture of the Baghera platform was conceived based on the AEIO (Agent, Environment, Interactions and Organisation) methodology for a multi-agent-oriented analysis and design, in an iterative process [13]. As a result of this process, students and teachers interact with different agents, according to the activities they will carry on and the educational approach of Baghera. Each student is supported by three artificial agents:

- *Companion - Student's Personal Interface Agent*
  It is an agent associated with the student's interface with a wide range of goals. Mainly it monitors the student's actions, notifying other agents when needed and giving access to system

resources. This agent controls the access to the student's electronic folder and can interact with tutor agents, teachers' companions, and other students' companion agents. From these interactions, the companion brings to the student information about the whole environment and allows the student to communicate with teachers and other students connected.

- *Tutor Agents*
  A tutor agent can interact with mediator agents, assistant agents, other tutors, and companions. It can access the student's electronic folder to retrieve exercises, add new ones and update student's history. This agent can request the proof verification, obtain information about the student's history and send information about the student's current activities to teachers' companions. In addition, tutor agents are notified of new connections of students and teachers belonging to the student's class. We have been working on the development of tutor agents able to model students' conceptions. Tutor agents will be didactic agents whose didactic decisions are based on these students' conceptions diagnosed.
- *Mediator Agent*
  The aim of this agent is to choose an appropriate problem solver to send the student's solutions. In the case of learning of geometry proof, this agent is supported by the automatic theorem prover called ATINF [8], being able to perform proof verification, propose alternative proofs and build counter-examples. Besides these functions, this agent implements techniques to analyse and present proofs. It can interact with tutor agents.

Similarly, each teacher is supported by two following artificial agents:

- *Companion - Teacher's Personal Interface Agent*
  This agent is associated with the teacher's interface. It brings to the user information about the whole learning environment. This agent mediates interface functions related to communication with other human and artificial agents, as edition of new activities to the students, distribution of such activities to students, and supervision of work done by students. The teacher's companion can interact with the assistant agent, tutors, and any companion agent.
- *Assistant Agent*
  An assistant agent is also a kind of personal agent whose goals include assisting the teacher with the creation and distribution of new activities, which are kept in the teacher's electronic folder. This agent controls the access to the teacher's electronic folder and, when demanded, it hands the activities out to students. The assistant agent can interact with tutor agents, other assistants, and companions. In addition, assistant agents are notified of new connections of students and teachers belonging to the teacher's class.

The Baghera platform is an open multi-agent system: the number of agents in the society increases or decreases depending on the number of users logged in. For instance, in a specific moment, given a number n of students and m of teachers logged in, the number of active artificial agents is 3n+2m. We consider this an important remark since the number of connections is not limited and the number of agents is not fixed in the society. We demonstrate the dynamic behaviour of agents through the examples presented in the next section.

## 3 A web-based environment for teaching geometry proof

Existing educational software has validated approaches for teaching the construction of proofs in geometry [1,20]. However, our approach is strongly founded on the extensive work done by Balacheff [2] and Luengo [18] on the learning of mathematical proof. The prototype of the environment for teaching geometry proof is based on the multi-agent platform just presented.

Users have access to the learning environment by connecting to the Baghera web server (http://www-baghera.imag.fr), via any browser supporting Java applets, and logging to the application. The students' interface is first presented as shown in figure 1-a. From this window students have access to the class they belong to, the exercises to be solved and, from the bottom of the window, students can establish a simple dialogue with their personal interface agent. Once a student has chosen an exercise to work on, EuclideJava (figure 1-b) is started.

Figure 1-b shows one solution constructed by the student Marc. On the top of the window there is a menu and the statement of the exercise. The rest of the window is divided in two parts. The left part is used by students to construct the proof. In the right part a geometric object is placed for geometric manipulation. The geometric manipulation is done by Cabri-Java [7], a java applet interface that allows dynamic manipulation of geometric objects.

At interface level, the proof verification is very limited. However, once the student considers to have finished the proof, the solution is translated into first order logic and sent to the mediator agent, who takes charge of proof verification by sending it to the theorem prover. Additional details of the automated reasoning module ATINF can be found in [8].

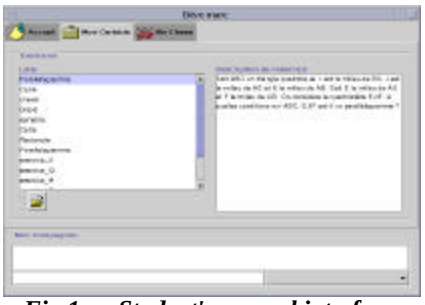

***Fig.1-a - Student's general interface.***

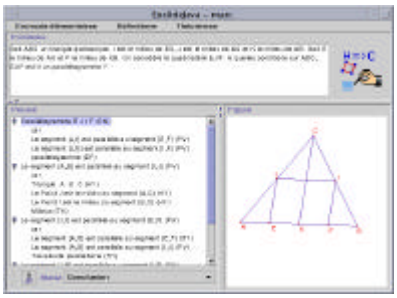

***Fig.1-b - Student's problem solving interface.***

The teachers interface is similar to the student's general interface. Extra functionalities in the application allow teachers to insert and distribute new problems, supervise students while they are working and exchange messages. Students and teachers are dynamically organised in virtual classes according to their level. Virtual classes determine sub-societies of agents, students and teachers. Members of the same virtual class can see each other and exchange messages.

## 4 Conclusion and Perspectives

Through Baghera we intend to develop an educational community composed of human and non-human agents, all having their own point of view, who cooperate and work together for the education of students. Current achievements include a web-based environment for teaching geometry proof, whose multi-agent architecture has been presented here.

Besides improvements in the prototype, we have been working on modelling students' *conceptions*. The notion of *conception* is used to represent students' knowings [3]. We recognise that *conceptions* could be right or wrong - as the so-called misconceptions - but in any case they exist because there is a domain in which they are sufficient to solve problems [12]. Based on this view we argue that there is no unique didactic strategy but a lot of locally applicable strategies depending on current students' *conceptions*. Therefore, the educating function of a system will be an emerging property of the interactions organised between all the different agents, which implement the various didactic strategies, specific diagnostics of conceptions, dedicated problem solvers (as ATINF), as well as learners and teachers, and not just the functionality of one of its parts.

Why Baghera? Because the core of the intended system will be a society of non-human agents whose interactions will be aimed at the education of a human learner. But unlike the famous Jungle Book, this time some human agents will take part in the adventure...

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