A DOMAIN AND PLATFORM INDEPENDENT ARCHITECTURE FOR PRESENTATION OF AFFECTIVE BEHAVIORS OF ANIMATED PEDAGOGICAL AGENTS

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Abstract: This article presents the architecture and the implementation of a module responsible for the presentation of verbal (speech) and corporal (animation) behaviors of animated pedagogical agents. This module is independent of domain and application, being able to be inserted in any learning environment apart of its application domain, and independent of platform, making possible that it can be executed in different operational systems. It was implemented as a reactive agent in Java (what makes it independent of platform), called Body agent, that communicates with the agent's mind using the agents communication language FIPA-ACL. This last capacity of the agent allows it to be inserted in other intelligent learning environments, if they are also able to communicate in FIPA-ACL.

Keywords: animated pedagogical agents, emotions, affective computing, lifelike agents.

1. Introduction

Due to the motivation aspect of lifelike characters, computational systems have been enriching their interfaces with characters that exhibit facial and body expressions . These human characteristics, associated with a good dialogue interface with the user, will make the system more attractive because they explore more natural modes of interaction with the user. In education, for example, some works employ animated agents for the presentation of pedagogical content to the student, as also for doing demonstrations, with the aim of engaging the student and motivating him [Lester *et al.* 1997b; Paiva and Machado 1998; Burleson and Picard 2007]. These agents are known as Animated Pedagogical Agents.

Animated Pedagogical Agents are intelligent agents that have a pedagogical or educational role to facilitate or improve learning and which are personified by lifelike characters that interact with the student. These agents use multimedia resources to provide for the user[1] an animated character with characteristics similar to the ones of living intelligent creatures. Thus, differently from the conventional systems, the animated pedagogical agents communication has a more anthropomorphic and social nature. They exploit the natural tendency of people to engage in social interactions with

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[1] In this paper, students and users are synonymous, since we just consider users of intelligent learning environments (who are also students in these environments).

computers, termed The Media Equation by [Reeves and Nass 1996]. As some examples of Animated Pedagogical Agents, we can mention: Adele [Johnson *et al.* 1998], Steve [Rickel and Johnson 1996], Vincent [Paiva *et al.* 1999], Cosmo [Lester *et al.* 1997b] and others. The use of animated pedagogical agents for educational purpose opens new interesting possibilities for computing learning systems since, for example, the agents can demonstrate tasks [Rickel and Johnson 1998], use locomotion and gestures for focusing the student's attention on the most important aspects of the task [André *et al.* 1999] and to respond emotionally to the student [Faivre *et al.* 2002; Burleson and Picard 2007]. The animated pedagogical agents offer great promise for increasing the communication capacity of the educational systems [Johnson *et al.* 1998] and increasing the ability of these systems to engage and to motivate the students [Lester *et al.* 1997a].

The architecture of animated pedagogical agents is generally composed by two main modules [Paiva and Machado 1998; Jaques 2004]: the *(i)* Mind, responsible for updating the student's model and choosing an appropriate affective tactic to apply; and the *(ii)* Body, which aims at exhibiting the agent's verbal (speeches) and behavioral (animations) actions that represent the chosen tactic. Although the agent's mind should be designed specifically for the educational environment where the lifelike agent inhabits, since it considers the student's profile, the educational subject and the pedagogical theory that founds this system; the functionalities of the Body are, in general, the same in all educational systems, mainly, when they are a web one. However, usually, it is necessary to develop a new implementation, since, in general, these systems use platform dependent technologies or the agents are designed specifically to work in a determined environment.

This paper describes the architecture and implementation of an open-source body module for 2D animated pedagogical agents, which is independent of domain and platform, and that the main goal is to be reused in other learning environments. In order for the proposed Body module to be domain and application independent (it means, it can be inserted in other applications developed for other subjects) and platform independent (it can be inserted in educational environments that execute in different operational systems), this module was implemented as a reactive agent in Java [Horstmann 2004], called Body agent, which communicates with the Mind module through the agents communication language FIPA-ACL [FIPA 2002]. This last agent's functionality allows it to be inserted in other learning systems, if they have the ability to communicate with other agents using FIPA-ACL.

2. Related Works

Cosmo is an agent that inhabits a learning environment, the Internet Advisor, for the domain of Internet packet routing. Its function is, in real time, to demonstrate and to advise students about the best way to ship packets for one definitive destination, in a virtual world of routers [Lester *et al.* 1997b]. Cosmo has the appearance of a strange creature with antennas and it is very similar to a small humanoid robot. It can carry out a large variety of behaviors, such as moving, pointing, blinking the eyes, inclining, beating palms and raising and folding its antennas. Moreover, as verbal behavior, it has 240 elocutions that vary between 1-20 seconds. One of the components of the architecture of Cosmo is the **Emotive-kinesthetic Behavior Sequencing Engine** [Lester and Towns 2000], which is responsible for mounting and selecting the visual attitudes that are shown in a determined situation. This module was based on the framework Affective Reasoner [Elliott 1997], which associates emotional states to communication. Cosmo has a repertoire of corporal emotive behaviors associated to

speech acts in accordance to its intention or kinesthetic expression. When the Explanation System is invoked to construct a communication plan, it examines the state of the problem, an information net about the course and the student model to determine the pedagogical speech acts that will be used to communicate to the student. These speech acts are sent to the Emotive-kinesthetic Behavior Sequencing Engine that selects an emotive behavior among all behaviors that express the appropriate affective state of the speech act. This is possible because all behaviors in Behaviors Space are mapped, one by one, in emotive states that they express. The main differences of Cosmos's **Emotive-kinesthetic Behavior Sequencing Engine** and the proposed Body Agent is that the former is totally dependent of platform and can just relies on a pre-fixed number of verbal behaviors since the elocutions are records. Besides, the images that compose the animations in Cosmo are associated with information about the emotional state of the agent and not with the affective state that the agent aims at promoting in the student, as is the case of this work.

One of the first works to address the presentation of behaviors of an animated pedagogical agent that had the purpose of teaching in a web-based learning system was [André *et al.* 1997; André *et al.* 1999]. The authors create a script language in order to determine the behavior sequence of the agent. Although the language allows determining the behavior of different agents in any web application, the language did not considered the presentation of emotional behaviors.

Recently, several works [Faivre *et al.* 2002; Pelachaud and Poggi 2002; Rehm and André 2005; McQuiggan and Lester 2007] have been proposed architectures for 3D embodied agents that are able to show emotional behaviors. In these works, the agents have a emotions synthesis architecture that is responsible for evaluating the situations in the environment and labeling the state of the agent as an emotion. Again, the module responsible for presenting emotive behaviors aims at selecting those actions that corresponds to agent's emotions and not with the affective state that the agent aims at promoting in the student. It is important to consider that virtual agents can experience emotion, as for example to become nervous with student, which can not be the most appropriate reaction for student's learning. Besides, these architectures are created for 3D agents, generally conceived to inhabit 3D worlds.

3. Agent's Description

This work considers the Body and Mind module of an intelligent and lifelike pedagogical agent as autonomous agents that communicate among themselves. The agent's Mind is an intelligent cognitive agent, responsible for the affective and intellectual diagnostic of the student, as well as to determine the better pedagogical tactic to be applied. In the other hand, the Body Module is a reactive agent that shows a physical and verbal behavior of the agent that better represents the chosen tactic. For example, if the Mind chooses the tactic "increase student self-ability" (used by the agent Pat [Jaques *et al.* 2004]), that aims at increasing student's own judgments of what s/he can do with whatever skills s/he has, the Body should choose a verbal and a physical behavior in order to apply this tactic. In this section, we describe the architecture of the developed agent that allows it to choose in a random way different behaviors for the same tactic in order for the agent to be believable.

3.1. Description of the Agent's Databases

As we mentioned in the previous section, the Mind chooses a pedagogical tactic to be applied and sends this information for the Body agent. In order for the agent to be

believable, i.e., to generate the illusion of life and then allow the suspension of disbelief [Bates 1994], it should exhibit different behaviors for a same situation. Otherwise, the agent's behaviors can be mechanical and repetitive, which makes them foreseeable for the students and thus boring.

The agent has 3 main databases: (*i*) a tactics database, (*ii*) a behaviors database, and (iii) an agent's database. The tactics database contains a list of all possible tactics and the *type of behavior* that can be presented for that tactic. The type of behavior is an intermediary level between the tactics and the behaviors of the agent. It is useful to have this intermediary level, since different tactics can be represented by a same type of behavior. The behaviors database is composed by all physical and verbal behaviors of the agent. A physical behavior is a set of 2D pictures in gif format. In fact, the database contains the localization of the directory that contains this set of pictures. Verbal behaviors are sentences stored in the database to be spoken by the voice synthesizer. Each behavior is associated with a behavior's type. The number of verbal behaviors can be easily increased, since we use a voice synthesizer and, thus, the only work to be done is to add the sentences in natural language in the database. The physical behaviors, otherwise, must be designed by a professional designer, but can also be easily add by the specific interface of the system. Finally, the agent's database contains a list of all agents available for the system in order to allow the student to choose a determined character among several. As we use a voice synthesizer for the agent, this database also stores the voice timbre for the desired character that can be: child-female, young-female, adult–female, aged-female, child-male, young-male, adult–male, and aged-male.

3.2. Database Information Manager

The Body agent can be entire configurable. The user can add new tactics, behaviors types, animations, speeches, characters and yet configure information about time interval for showing believable behaviors. The agent has an interface to manage this information. This interface was implemented in Java and is quite intuitive.

3.3. Agent's Architecture

The architecture of the Body agent is composed by 3 main modules: (*i*) a communication module, which handles FIPA-ACL messages sent and received by the agent; (*ii*) a behavior manager, which chooses a verbal and physical behavior to be shown according to the tactic to be applied, (*iii*) and the animation generator, responsible for generating the animation of the physical behavior chosen through the images files that compose it. Figure 1 shows the Body agent's architecture.

The agent works as follow: the Body agent receives a message, containing the tactic to be applied, from the Mind agent. The Body agent's communication module handles the message to know its purpose. If the message contains a tactic to be applied, the agent sends it to the Behavior Manager module that verifies in the database which type of behavior composes this tactic and randomly chooses an animation and speech of that type to be exhibited. The behavior and speech identifications are sent to the Animation Generator that makes a dynamic animation from the image files that compose it. The Behavior Manager also lunches the voice synthesizer for the speech.

The image files are stored in a repository called Images. This repository is composed of several directories that organize the images files. For example, the directory "TEACHER" represents the respective character, and the sub-directories

"Applause", "Walk" and "Call" store the files that compose each one of these physical behaviors of the character Teacher. In the directory "Applause", the files are named applause00, applause01, ..., applause10, for the agent to know the order that the images should be composed to generate the animation.
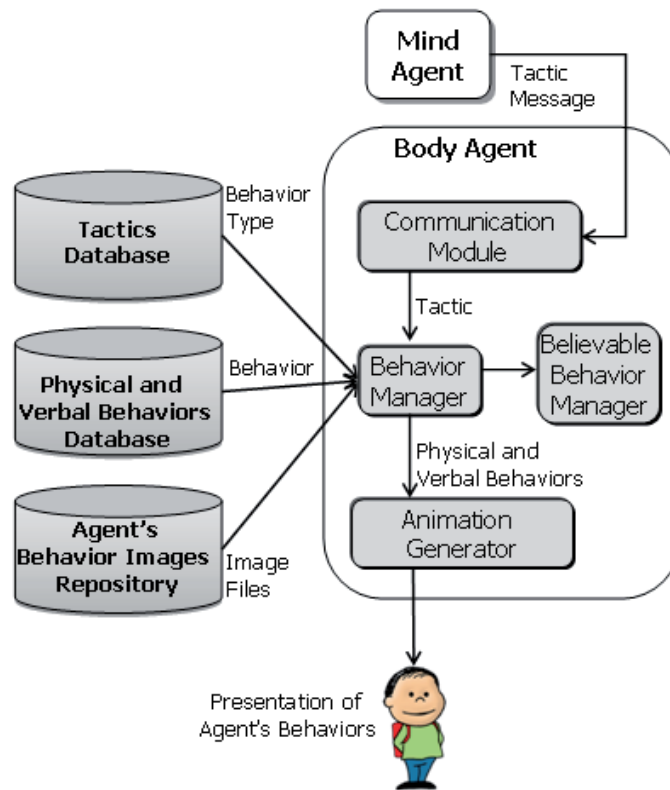

Figure 1. Body Agent's Architecture

All the modules of the Body agent were implemented in Java. As voice synthesizer, it was used FreeTTS[2] v1.2, a free synthesizer, which follows the Java Speech API specification. For the implementation of database, it was used MySQL[3]. Besides, the agent can be inserted in web-based learning environments, as a Java applet, as well as in stand-alone applications, as a separate frame.

3.4. Communication with other agents

The communication with other agents is made according to the standard FIPA. It was used the framework FIPA-OS[4], since it was developed in Java and has all the resources established by FIPA, including threads for handling communication in FIPA-ACL. Bellow, we can see an example of a message handled by Body agent:

(request

   :sender (agent-identifier :name Mind@localap)

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[2] http://freetts.sourceforge.net/docs/index.php

[3] http://freetts.sourceforge.net/docs/index.php

[4] Available at: http://sourceforge.net/projects/fipa-os/

:receiver (agent-identifier :name Body@localap)

:content "Tactic=IncreaseStudentSelfEfficacy"

:language "BodyAgent"

:protocol fipa-request)

The example above is a message received from the Mind Agent, which identifier is "Mind@localap". This message says to the Body agent that it should apply the tactic "IncreaseStudentSelfEfficacy". The message was described in a simple language created for the agent, called "BodyAgent". When the agent receives this message, it sends it to the Behavior Manager, which is going to show the corresponding behaviors.

4. Available Characters

In order to define the character appearance, we firstly developed a questionnaire, with the help of a psychologist and a pedagogue, in order to determine the desirable appearances for the character. This questionnaire was answered by 5 primary school teachers, since we intend to apply Body agent in an intelligent learning environment that was developed for 8-9 years children, called Civitas [Axt *et al.*, 2008]. The results of the questionnaire allow us to define the following desirable characteristics:

-   the user should have the option of choosing a character among several;

-   the characters should appear intellectual and happy;

-   the characters should be a full-length one and should have approximately 10 cm;

-   the student should have the option of choosing a character among several;

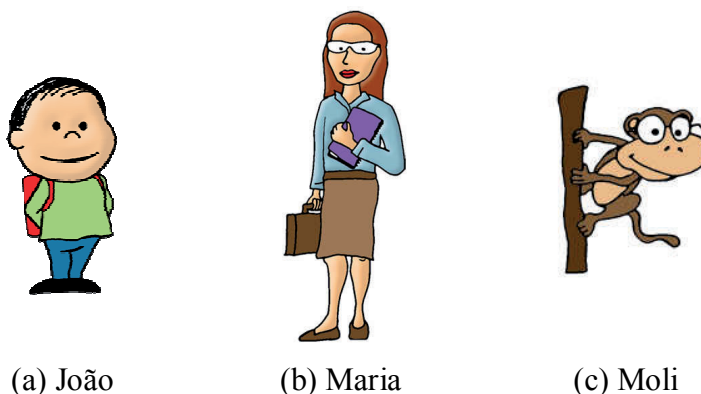-   the system should allow the student to hide/show the character;

(a) João   (b) Maria   (c) Moli

Figure 2. Available Characters

Based on the teacher's answers, we opted for designing various characters and allowing the students, when accessing the environment, to choose the preferred one. This option was also implemented since previously studies showed that users prefer to interact with characters that match their own appearance and personality [Reeves and Nass 1996]. Besides, early experiments made by our group showed us that users prefer to choose the appearance of the character with they interact with [Jaques 2004].

Currently, tree different characters were created by a professional designer. Figure 2 illustrates the available characters: a boy, a woman teacher, and a monkey pet. These characters were chosen due to the age group of students that will interact with the environment where Body agent will be inserted. The boy has the same age of students who will access Civitas [Axt *et al.*, 2008]. The female represents their teachers (in

general they are young female); and the monkey was chosen since children like and are familiarized to interact with pets that think and speak, as in cartoons.

5. Believability in Body Agent

In order to turn the animated pedagogical agent more real to the user, it must be believable, i.e., the student involves himself with the agent in such a way that he believes the agent is real [Bates 1994].

According to Loyall and Bates (1997), the term 'believability' is used in the sense of believable actors in the dramatic art, meaning that the public or users can forget their skepticism and feel that the character or agent is real. To make an agent believable involves providing it with the aspects to express its personality. An agent which represents an interactive and believable animated character is called Believable Agent.

There are some actions that turn the agent more real, such as the eyes movement, a pause to speak, the conscience of the body position and of the personal space, and communication in natural language.

According to Hayes-Roth (1998), in order for an animated agent to have and to maintain credibility, the agent animation behaviors must follow some premises:

- There must have a varied repertoire of different behaviors to cover a great number of situations;

- There should be variability in the expression of a nominal type of behavior so that it looks more alive and less robotic;

- The environment must not distract the user, but must keep it alive during dramatic events;

- There must be ambiguous behaviors that can be used in different contexts;

- There should be attenuation of the behaviors so that the observers experience a distribution of the expressive effect, requiring different levels of interpretation;

- There should be signature behaviors that occur with some frequency in a context to designate the key qualities of the character;

- The character must have particular attitudes that differentiate it from the others.

In order to be believable, the agent should show kinds of behaviors that are not directly related to pedagogical activities. For example, the agent can tap the foot on the ground or breathe when it is idle. In order to make our characters more visible, we designed some physical behaviors for João, Maria and Moli. João can tap the foot on the ground, yawn or sit in a chair. Maria cleans her glasses or read her book. Moli makes some acrobatics and scratch his head. These believable behaviors are controlled by the Believable Behavior Manager, BBM (see Figure 1). When the Behavior Manager (BM) finishes showing a behavior, it activates the BBM that randomly shows the agent's believable behaviors in each 3 minutes. Besides, BBM is also responsible for showing the believable behavior "blinks" in each 5 seconds. When a tactic arrives, BM deactivates BBM and reactivates it again when the behavior tactic was showed.

But, we must always remember that the pedagogical agents' goal is to promote learning. In this case, the <u>agents behavior must increase its believability, without reducing the learning effectiveness</u> [Johnson *et al.* 2000]. All behavior that intervenes in the resolution of the problem by the student, regardless of how much they contribute to agent believability, is inappropriate. For example, if the agent makes acrobatics in the

screen while the student is carrying out a difficult exercise, it would immediately break the student's concentration. In order for the agent respect the criterion of controlled visual impact, which aims at keeping the student's attention in the pedagogical activity, we implement a mechanism of control of believable behavior. When the student is accomplishing a task that requires some level of concentration, the Mind agent sends a message to the Body agent that deactivates the exhibition of believable behaviors. In fact, the unique believable behavior that is still shown in this situation is "to blink". The Body agent activates the believable behaviors once it receives a specific message of the Mind agent or after 5 minutes. It is important to say that all this information of time can be configured in the agent by the interface of Database Information Manager.

6. Conclusions and Future Works

In order to test the body agent, it was developed a simple environment that simulates the Mind Agent, since this work will be used in the future in a master thesis for the implementation of a lifelike interface agent. This interface allowed us to simulate the Mind agent sending a tactic to the body agent and to study the behavior of the agent.

As a future work, we plan to use XML files, instead of a database, for the persistence of information in the system. The use of XML files allow to use the Body agent in embedded systems, as mobile phones, for example.

Another improvement that can be done in Body agent is to make available with the installer, an automatic software for searching in a server new characters and updating available behaviors for the existing ones.

The Body agent is being used for representing the character of a lifelike pedagogical agent that has as goal to assist students who have hearing impairment, communicating with them in sign language.

7. Acknowledgments

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