AUGMENTED REALITY BASED INTELLIGENT INTERACTIVE E-LEARNING PLATFORM

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Abstract: e-Learning systems are continuously evolving in order to include new technologies that improve the education process. Some of the technologies that are being incorporated to the e-learning systems are related to virtual agents and Augmented Reality. The proposed architecture aims to offer a novel platform for non-programming experienced users to develop intelligent Augmented Reality e-learning applications by an intelligent fuzzy-rules-based framework. The applications consist of a series of interactive Augmented Reality exercises guided by an intelligent adaptive virtual tutor to help the student in the learning process.

1 INTRODUCTION

Nowadays, e-learning systems are focused on including new emerging technologies that enhance the learning process. The concept of Augmented Reality (AR) refers to the representation of virtual elements (such as 3D models or images) over a real scene captured by a camera. AR has been proved to be a useful tool in the learning process (Balog, Pribeanu and Iordache, 2007; Chen, Su, Lee and Wu, 2007; Kaufmann and Dünser, 2007). Students find the concept acquisition more attractive and fun when a virtual environment is mixed with the reality. Opposite to other new technologies, AR usability has a fast learning process. Even users who have never used any AR application before have reported a good feedback in the use of this technology for education purposes (Sumadio and Rambli, 2010). Some examples of AR applications for e-learning purposes can be found in the literature such as the MagicBook where a traditional book is augmented to offer virtual content (Billinghurst, Kato and Poupyrev, 2001), a book with finger marker used to enhance the contents (Hwa Lee, Choi and Park, 2009) or an application to learn concepts related with the human body (Juan, Beatrice and Cano, 2008). However, those applications do not show any available kind of interaction or it is very limited. The purposes of those works are mainly limited to show virtual 3D contents to the users who can see some objects under different angles and dimensions and better understand how they work. The main gap between AR applications and educators is the lack of programming skills of the educators. Because of that, the creation process involves computer science experts and pedagogic professionals. Some user-friendly authoring tools have arisen to help those people who don't have programming knowledge to make some simple but powerful AR applications. Some authoring tools examples can be ATOMIC (http://www.sologicolibre.org/projects/atomic/en/index.php) and ZooBurst (http://alpha.zooburst.com/). However, the created applications are limited to show contents and the logic of the program is fixed by the software creators.

The use of 3D environments opens the door to the use of intelligent virtual agents. In the field of e-learning, the benefits of using virtual humans able to adapt the transmission of knowledge to each student have been proved (Sklar and Richards, 2006). It is important that the virtual agent shows intelligent behaviours that respond accordingly to the evolution of the interaction, like, for instance, offering help when needed.

The proposed platform is a new intelligent interactive e-learning platform based on AR. The

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presented platform is oriented to create intelligent AR applications for learning purposes. Instead of just showing contents, the final applications are able to offer a rich variety of interactive actions. The platform uses an intelligent framework that enables to define application logic using natural language. Therefore, any non-programming expert person is able to create interactive AR exercises for e-learning with his/her mind as the only limitation.

One of the main features of the proposed platform is the introduction of a virtual tutor. It is an intelligent adaptive virtual agent who guides the user through the learning process and evolves his behaviour in function of the user's actions, making the exercises more interactive.

Thanks to the applications created with the proposed platform, the traditionally acquired learning concepts can be moved into practical exercises. Due to the attractiveness of some of the technological elements included in the platform, such as AR exercises and virtual tutors, the learning process becomes more interesting for students.

The rest of the text is organized as follows: section 2 describes an overview of the proposed platform architecture. In section 3, a practical example is explained to show the potential of the platform. Finally, in section 4 some conclusions and future work are discussed.

2 PLATFORM ARCHITECTURE OVERVIEW

This article presents an intelligent AR e-learning platform. The main element of the architecture is the intelligent framework in charge of the e-learning process which also controls the virtual 3D environment implemented to offer virtual content (including a virtual tutor).

The control logic in the e-learning platform is implemented inside of the intelligent framework using natural language rules (fuzzy rules). This framework is also responsible of the behaviour of the virtual tutor. This intelligent e-learning platform is able to evolve and adapt according to the actions obtained from the user. During the learning process parameters like the number of exercise repetitions or increasing the level of difficulty of the exercise are adjusted by means of a supervised learning.

Thanks to the rules-based intelligent framework, the proposed platform is a powerful tool for general e-learning purposes. The platform can be adapted easily to any kind of subjects and contents, and the exercises can be designed by any person even if he or she does not have programming knowledge, thanks to the natural language rules programming.

In order to study off-line the user's progress and his/her interaction with the exercises, the tutorial stores some learning indicators in each session with relevant data: time used to solve an exercise, number of times he or she makes a mistake, history of questions introduced in the help chat, trajectories followed by the markers, etc in order to analyse the e-learning interaction process by one expert.

Figure 1 shows the proposed architecture. The user interacts with the platform through different elements (webcam, keyboard and mouse, microphone and markers). Those inputs are treated to evolve the platform through the intelligent framework called ISIS (Intelligent Support Interaction System) which is the element in charge of the logic of the platform control. ISIS communicates with the virtual environment (a full multimedia engine) which shows the final result in the monitor.

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2.1 The Intelligent Support Interaction System (ISIS)

ISIS is the main element of the proposed application. It is the evolution of a softcomputing-based intelligent system called PROPHET that enables real-time automatic fuzzy decision making and self-learning over any kind of incoming inputs (from sensors, video channels, audio channels, probes…). The system has already been successfully used in different domains such as logistics decision making systems (del-Hoyo, Ciprés, Prieto, del Barrio, Polo and Calahorra, 2007), real-time networking management (del-Hoyo, Martín-del-Brío, Medrano, Fernández-Navajas, 2009), virtual emotional agents (Hupont, del-Hoyo, Baldassarri, Cerezo, Serón and Romero, 2009) and natural language automatic analysis (del-Hoyo, Hupont, Lacueva, and Abadía, 2009).

ISIS is the engine in charge of the logic of the platform from the tutor point of view. It is also the inference engine that makes the virtual tutor to react to different inputs coming to the platform.

According to different inputs of the platform, ISIS extracts knowledge and thanks to the use of Neuro-Fuzzy techniques (Lin and Lee, 1996), the module has the capability of self-extracting and self-learning new fuzzy decision rules from historical data.

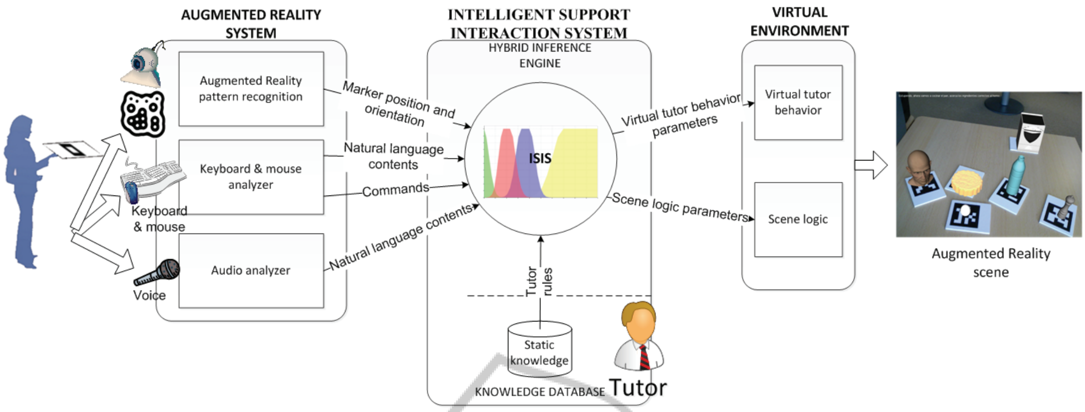

Figure 1: Proposed platform's architecture.

ISIS consists of a set of modules for pre-processing, integrating and extracting information and making decisions in a flexible way under uncertain contexts. The system is based on a state machine in order to increase its scalability: each module generates events that are treated asynchronously inside the state machine. A brief description of the different modules that compose the system is presented in the following sections.

2.1.1 Information Pre-processing and Integration Module

This module is in charge of inputs' pre-processing, integration and synchronization. The inputs come from any source of information: webcam, keyboard and mouse, microphone and markers. The system has several pre-defined filters (e.g. data normalization filters), but also allows the free definition of any kind of expert pre-processing rules (e.g. truncate an input value if greater than a given threshold, accumulate data values…).

2.1.2 Automatic Knowledge Extraction and Classification Module

This module extracts knowledge from input data, by means of softcomputing-based algorithms. Thanks to the use of Neuro-Fuzzy techniques, the module has the capability of self-extracting and self-learning new fuzzy decision rules from historical data.

2.1.3 Hybrid Rule Engine

The embedded rule inference engine is in charge of rule-based decision making tasks in the e-learning process. It is a hybrid rule inference engine since it can both deal with crisp rules (applied to exact inputs' values) and execute inference from rules that handle fuzzy concepts. Fuzzy rules can be defined over the inputs whose fuzzy membership functions have been previously configured in the system. The elements in the inference engine's Working Memory are not only the rules pre-defined by an expert, but also the set of automatically self-learned decision rules created by the knowledge extraction and classification module.

Figure 2 shows an example of fuzzy rules definition using the interface of the ISIS framework.

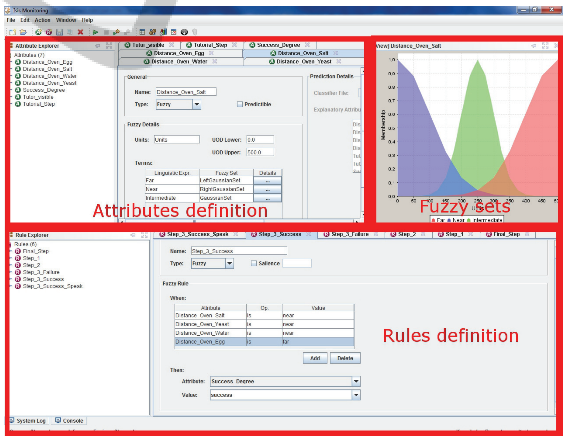

Figure 2: Screenshot of the ISIS tool for Fuzzy rules definition. The screen is divided in two parts. The first one is used to define the attributes (the definition of fuzzy attributes is accompanied of their fuzzy sets). The second part is used to define the platform rules.

2.1.4 AIML inference Engine Module

The AIML (Artificial Intelligence Markup Language) inference engine module is in charge of the virtual tutor dialogue. The module is full communicated with the hybrid engine in order to generate text events to the virtual tutor, modify internal variable values or change the tutor dialogue

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context (for example in which exercise is the student).

2.2 Augmented Reality System

The Augmented Reality system used is based on pattern recognition through computer vision algorithms. In particular, the ARToolKit Plus has been used. The ARToolKit Plus is an extension of the popular and widely used ARToolKit library (www.hitl.washington.edu/artoolkit). The original ARToolKit is an open source library developed to detect markers over the scene captured by the camera. The detection of the markers is carried out by pattern recognition being the detection algorithm invariant to perspective and scale variations.

It requires a computer with a standard USB camera to run. It is also necessary to have the appropriated markers needed by the system which are the patterns to be recognized. The camera captures the motion of the scene and the system detects the position and orientation of the visible markers. Each marker has internally associated one or more virtual elements (3D models, text, images…) which are located in the scene according to the marker position. The final result is a real time compound motion of real and virtual elements that is displayed on the computer screen.

The exercises consist of some 3D objects located over the markers with which the user can interact. The user is instantiated to take the objects needed to carry out the exercise, interact with them, change their properties, etc.

The output of the marker detection is a matrix which represents the relationship between the marker's position and orientation and the camera. This matrix is used to properly locate the 3D models in function of the markers' position. This information is transmitted to ISIS.

An Automatic Speech Recognition (ASR) system has been also integrated to make the virtual tutor understand the user's voice. Due to the lack of open source Spanish ASR systems, the commercial Loquendo system has been used. One of the features of the system is to let the user to communicate with the virtual tutor through a chat. Both communication systems (voice and chat) send the text strings to the ISIS system where the responses are obtained and returned to the virtual environment. The communication between ISIS and the virtual environment is carried out with the XML-RPC protocol.

2.3 Virtual Environment

The AR concept requires virtual elements to merge with the image of the real scene. In order to obtain a virtual environment where the virtual action takes place, a powerful engine has been developed integrating some libraries (most of them open source). The 3D rendering engine used has been Ogre 3D (http://www.ogre3d.org). Ogre is an open source 3D graphic engine that enables to work with 3D objects and animations. The sound is an important needed feature for the system proposed, so an open source API called OpenAL has been integrated in the system. A TTS (Text To Speech) system to make the tutor talk is required. In the presented engine, two TTS systems have been included. The first one is an open source TTS called Festival. The second one is the commercial solution Loquendo. Finally, a WEB HTML 5 library has been adapted to include HTML content in the 3D virtual environment. Thanks to the library, any kind of webpage content is properly located in the 3D world. As it is a Chrome based browser, the same features of the Google's browser are implemented, included some features available on the html5 specification, like the video tag.

One important figure in the platform is the virtual tutor (a human look-like 3D model), who is rendered in the virtual environment. He is the person in charge of guiding the user through the exercises. He also responds in an intelligent way to the actions made by the user as wrong answers, help questions and so on. The virtual tutor behaviour is controlled by ISIS so he is able to interact with the user in an intelligent natural way. There are different ways to interact with the user. The most common way is by reacting to the action of the user, such as showing approval gestures or offering help if he thinks the user needs it. In those cases, the tutor's face may change according to the user's correct actions or mistakes. Another possibility of interaction is the chat mode. The user is able to chat with the virtual tutor through the keyboard. In some cases, the student will be offered to open a browser in order to display a webpage or to play a video with more detailed information. Apart from that, it is also possible to communicate with the virtual tutor in a conversational way using a microphone. In both cases (chat and conversation), the tutor will search in a question-answer engine and will answer as accurately as possible attending to the student's needs.

3 PRACTICAL APPLICATION

The platform has been used to develop a practical tutorial in order to show its potential. The tutorial consists of a series of practical exercises concerning to the bread production in a bakery. It should be mentioned that this is only an example, but the platform can be used in any field.

The general procedure of the tutorial is as follows. When the exercises begin, a welcome message is showed on the screen and also is played on the speakers. Every message is offered in both formats (text and audio) to enhance the comprehension of the information from the user. After the welcome message, the tutorial asks the user to locate the tutor's marker on the scene. Once the virtual tutor is visible, the exercise begins. Depending on the exercise, the virtual tutor may ask the user to locate a list of specific ingredients or cooking tools. When every asked object is visible, the virtual tutor indicates some actions to carry out, such as taking the correct ingredients to the oven or selecting the appropriate quantities of every ingredient. When the exercise is completed, a congratulation message is showed. Depending on the exercise, some extra information is showed, like some videos about the different processes of bread cooking, and finally the exercise finishes.

During the process of the exercise, the virtual tutor will help the user with his voice, but also with nonverbal communication. For example, by smiling to indicate approval or showing a sad face to indicate disapproval. It is also possible to chat with the virtual tutor through the keyboard to ask him for help. To open the chat dialog, a specific key should be opened.

At any moment, the user can ask the tutor for help or tell him to repeat the instructions through the microphone.

In Figure 3, an example of one of the exercises is shown. As it can be seen, the virtual tutor (represented as a human look-like head), an oven and a variety of ingredients are displayed over a real desk (Figure 3.a). The user is instantiated to locate the appropriate ingredients next to the oven. The quantity of the ingredients can be expressed using a fuzzy set. The distances from every ingredient to the oven are also fuzzy variables. An example of a fuzzy rule definition is as follows:

```
if ((Distance_Oven_Salt is near) and
   (Distance_Oven Yeast is near) and
   (Distance_oven_water is near) and
   (Distance_oven_Egg is far)) then
Success_Degree is success
```

When, according to the fuzzy rules system, the wrong ingredients are located next to the oven, the virtual tutor reacts with his gesture and voice (Figure 3.b). On the other hand, when the right ingredients are near the oven, the cooked bread appears and the virtual tutor smiles and congratulates the user (Figure 3.c). Once the exercise has been successfully completed, additional video information may be displayed on a browser to reaffirm the acquired concepts (Figure 3.d).

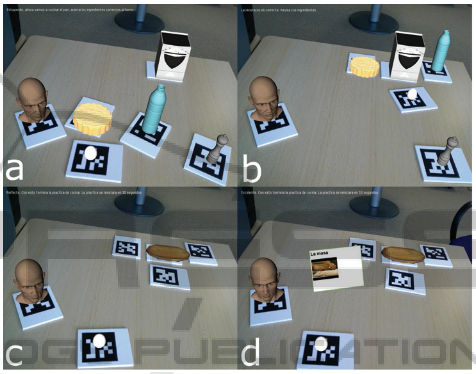

Figure 3: Example of one practical exercise. The user interacts with the ingredients to get the necessary ones to the oven. The tutor reacts to the user's actions and a video is displayed when the exercise has been successfully solved.

Figure 4 shows another example of interaction in the exercises. The platform offers virtual controls (buttons and selectors) to manipulate the properties of the 3D objects. In the image, the user is able to change the quantities of the ingredients to obtain the right mixture for the bread cooking. Those controls allow the real tutor to create more advances types of interaction, and adapt the exercises to the level of knowledge needed in every case. For example, the exercise showed in Figure 3 can be adapted to an upper level of difficulty making the user not only to include the right ingredients but also the right quantities, modelling them as fuzzy variables:

```
if (Water_Quantity is high) then
Success_Degree is failure
```

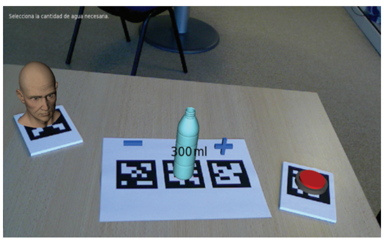

Figure 4: The user can change the quantity of water needed to cook the bread using the virtual controls.

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4 CONCLUSIONS AND FUTURE WORK

An intelligent interactive e-learning platform based on AR has been presented. The platform allows teachers to incorporate new virtual interactive exercises to the traditional learning system by defining natural language rules.

The user interacts with the platform by means of AR markers, where the different 3D models are represented. Moreover users can also interact with other virtual components (such as buttons, browsers…) in order to improve the user experience.

The user can also interact with a virtual tutor in a variety of ways (listening to the instructions, chatting, talking to him or receiving nonverbal communication). The virtual tutor acts according to intelligent framework, which is also responsible of the logic of the platform.

The platform is now being evaluated with users. The first evaluation results demonstrate that the proposed AR exercises are a useful way to engage the students in the learning process. It is an attractive method for the students thanks to the multimedia content offered and the possibility of interaction beyond the traditional pen and paper.

Besides, the virtual 3D representation of complex objects may be a help for the student to assimilate the concepts because sometimes it is difficult to visually image the objects.

In the future, the platform is expected to automatically analyze the learning indicators obtained in order to adapt the contents in real-time, instead of the mediation of the real tutor. Emotional detection for content adaptation is also a desirable feature to obtain in the future.

The platform is expected to be integrated in a standard Learning Management System. Another aspect to develop in the future is to recognize more user understandable patterns which have a visual relation with the 3D object associated, creating a new pattern recognition system.

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