# Enhancing Intelligent Pedagogical Agents in Virtual Worlds

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**Abstract:** Intelligent Pedagogical Agents (IPAs) are software agents which have educational purposes. They are able to communicate, cooperate, discuss, and guide other students or agents. Some studies conclude that if agents look like and interact as humans, they will enhance the learning process and the motivation of the students. This paper presents a proposal to add Semantic Web Knowledge to Intelligent Pedagogical Agents. In our solution, the IPA has a modular knowledge organization composed by four differentiated areas: (i) the rational area, which adds semantic web knowledge, (ii) the association area, which simplifies building appropriate responses, (iii) the commonsense area, which provides commonsense responses, and (iv) the behavioral area, which allows IPA agents to show empathy. Our main objective is to create more intelligent and more human alike Mentor IPAs, enhancing the learning experience of students in 3D Immersive Virtual Learning Environments for various learning settings.

**Keywords:** Virtual Worlds, Intelligent Pedagogical Agents, long-life learning, guided learning, linked open data

## Introduction

Virtual Worlds (VWs) represent social persistent worlds, generated through computer-simulated environments that allow interaction between avatars (i.e., the computer representation of users). This term is used in different ways such as simulated worlds, digital worlds, virtual environments, virtual reality, virtual worlds, or cyberspaces, by academics, industry professionals, and the media [4]. The first VW, still text based, was developed in the 1970s. Since then, a lot of VWs have been developed, and currently the use of 3D technology is a standard. The available VWs cover all topics of interest, although is in the education where they have attained noticeable importance during the last decade [5]. Examples of 3D VWs platforms are Open Wonderland [13] and Second Life [14].

Virtual Learning Environments (VLEs) integrate several educational resources to the learner including multimedia learning material, communication tools, recommender systems, etc. [16]. When VLEs are based in 3D VWs, they are called 3D Immersive Virtual Learning Environments, where the learners are immersed into the 3D VW being represented as avatars, and it is possible to meet other students or educators making the learning process very dynamic.

Intelligent Pedagogical Agents (IPAs) are software agents which have educational purposes. Their priority target is to stimulate the students to do their best in the learning process. One significant difference between IPAs and conventional computer-based learning environments such as Intelligent Tutoring Systems (ITS) is their ability to simulate social interactions, and to make use of non-verbal and verbal communication. This means that pedagogical agents are able to communicate, cooperate, discuss, and guide other agents

or students represented through avatars [6]. IPAs integrated in VLEs can play different roles such as provide intelligent visual appearance, intelligent navigation in the environment for pedagogical objectives, serve collaborative learning functions, and provide narrative and dialog functions guidance [16]. If agents look like and interact as humans, they will enhance not only the learning behavior, but also the motivation of the learning students [18].

To date, the majority of works found in the literature proposed two different functional roles for IPAs: (i) agent as an expert (knowledgeable), and (ii) agent as a motivator (supportive). We think that a new role is required, as a well performing human mentor does not simply transfer information, rather he or she provides guidance for the learner to bridge the gap between his current and desired skill levels, he should not be an authoritarian figure, but rather a guide or coach with advanced experience and knowledge that can work collaboratively with the learners to achieve goals, and he should demonstrate competence to the learner while simultaneously developing a social relationship to motivate him. Therefore, we propose a new approach: IPA as a mentor (knowledgeable and supportive). This insight has motived us to initiate a research project to design a novel approach to provide knowledge to Mentor IPAs integrated in 3D Immersive VLEs. These Mentor IPAs will be provided with knowledge based on semantic repositories, aiming to support students in their learning process. Our proposal may bring great benefits in computer-aided learning.

This paper is organized as follows: Section 1 describes the related work with regard to Intelligent Pedagogical Agents. In Section 2 we introduce the different problems that motivated our work. Section 3 details our proposed architecture. Finally, Section 4 presents some concluding remarks.

## 1. Related Work

When Virtual Learning Environments become greater with lots of available places to visit and learn from, guidance is needed. The intelligent guidance for learners in 3D immersive VLEs can be achieved by the use of IPAs, which should have pedagogical abilities and a suitable knowledge base to support learners to achieve their educational aims.
Previous research works regarding to IPAs which support learning in different fields can be found in the literature.

In [8] author gave an overview of current research on animated pedagogical agents at the Center for Advanced Research in Technology for Education (CARTE) at the University of Southern California. They developed some systems that, combining ITS with embodied conversational agents, help learners to acquire a variety of problem-solving skills in virtual worlds, in multimedia environments, and on the web. Examples of pedagogical agents developed are Steve [7] and Adele [15].

Steve (Soar Training Expert for Virtual Environments) is an agent designed to be a tutor for the students to perform physical and procedural tasks in the field of naval training. Steve demonstrates how to operate different devices, and the student can ask Steve to finish the task. In this case, Steve will monitor the student's actions and provide assistance. Examples of tasks supported are to control the engines aboard ships, or to inspect air compressors in the engines.

Adele (Agent for Distance Learning: Light Edition) is a case-based reasoning agent [1]. It is runnable at the student's computer since it is a web-based application. Adele has been designed for medical purposes, since it can help the students to perform a disease treatment based on a clinical case. Through Adele, the student is able to perform a variety of actions on the simulated patient, such as to ask questions about medical history, to perform a physical examination, to order diagnostic tests, and to make diagnoses and referrals.

Baldassarri et al. [3] presented Maxine, a script-directed engine for the management and visualization of 3D virtual worlds. Maxine can load models, animations, textures, sounds, embodied animated agents, etc., into a virtual representation in real-time. Despite being a very generic engine, it is oriented towards working with animated virtual actors in virtual scenarios. Maxine supports real-time multimodal use interaction by text, voice, image, and movement. This broadens the spectrum of potential users of the system by allowing interaction with people with special needs, and people of different ages and with different levels of education (i.e., people with or without computer knowledge). Three different applications using Maxine have been developed: (i) virtual presenters for PowerPoint-like presentations, (ii) interactive virtual teacher in the field of Computer Graphics, and (iii) control of a domotic environment.

Multitalker [17] is an intelligent agent primarily designed to tutor students while they try to work together on group homework assignments in Second Life. It was developed using Basilica, an event-driven framework, which enables development of conversational agents.

MultiTalker is expected to suggest actions and offer reflective advice when group discussions stall, or if progress towards the assigned goal seems to be staggering. When conversation dies down, becomes off-task, or unproductive, the agent waits a specified amount of time and interrupts with some reflective prompt, inviting members of the group to discuss some likely relevant aspect or their task. The agent will ask members of the group to answer questions, and it will confirm if answers are correct and follow-up with implications of the correct answers until productive students' conversation resumes.

To the best of our knowledge, although there are several research works regarding to the use of IPAs, none of them have studied how IPAs would support users in their learning process when attempting to find information through semantic repositories in immersive Virtual Learning Environments (VLEs).

## 2. Motivation

The use of VWs in education provides significant benefits for students and institutions [9]. These include: (i) education is not location-dependent, (ii) avoids discriminations since the users' avatars can be adapted in many ways, (iii) the simulation requires an active learning, (iv) educational experiments can be performed in different and unusual points of view, (v) enables students social interaction, (vi) supports high degrees of individualization not possible in classical classrooms, (vii) favors the international education (people or educators from other countries all around the world), (viii) offers great flexibility and numerous learning opportunities, and (ix) the educational support is available 24 hours a day, 7 days a week.

On the other hand, the use of IPAs in education also provides benefits to the educational process [16]. IPAs can: (i) increase the students' engagement, (ii) add value by giving new educational possibilities and computational-richness support, (iii) improve the interactions between the computer and the learner, (iv) act as a teacher, learning facilitator, or even a student peer in collaborative settings, and (v) act pedagogically on behalf or with learners.

Although the use of VWs and IPAs in education can favour effective computer-aided learning, these kind of learning environments present some drawbacks: (i) although the level of realism is being improved more and more, they lack of face-to-face interaction, (ii) require intelligent support and guidance, (iii) the use of 3D immersive environments can distract students from the main goals of the course, and (iv) IPAs usually are not human alike, or they are far from human appearance and behavior.

Integrating autonomous Mentor IPAs enriched with suitable semantic knowledge could mitigate some of the above problems, since semantic knowledge databases provide them documentation of knowledge, intelligent decision support, self learning, commonsense, and reasoning abilities [2].

## 3. Our Proposal

In this section we present our proposal in detail, explaining the different knowledge areas that an IPA should have in order to facilitate and improve the students' learning process in 3D Immersive VLEs. Figure 1 shows our proposed conceptual architecture. As shown, students can express a problem to the Mentor IPA about something of their interest, and it will provide them with a suitable answer. One important issue to be considered should be user modeling and understanding. Hence, user's parameters such as behavior, background knowledge, needs and preferences will be important for the IPA to contextualize its performance.

Our Intelligent Pedagogical Agent has four differentiated areas: (i) the rational area, (ii) the association area, (iii) the commonsense area, and (iv) the behavioral area. In the next subsections we explain them further.

When someone states a question or a problem, the IPA processes it, and performs different tasks: it searches in a Commonsense Knowledge Base, also in different Knowledge Bases, and tries to find the most appropriate emotion in this context. These tasks can be done in parallel, reducing its response time. Once, it has obtained the results, it makes the associations and builds the correct answer. In order to increase the level of realism, the interaction with the students could be done with voice.
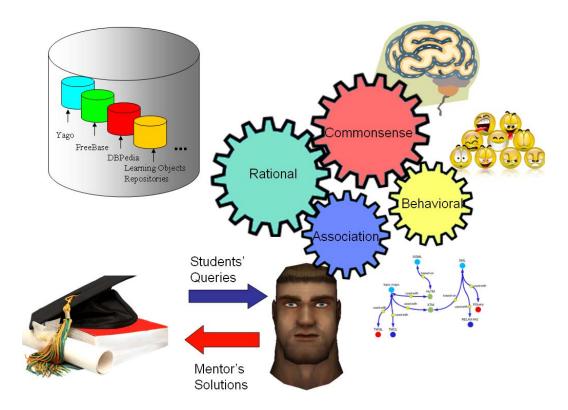


**Fig. 1.** Proposed conceptual architecture.

## 3.1 Rational Area

Our main objective is to provide Mentor IPAs with Semantic Web Knowledge, so this is one of the most important areas. The IPA will consult some different semantic web repositories to obtain the most suitable contents regarding the student's needs. We have decided to use both semantic repositories, enhancing Mentor IPAs with automatic reasoning about data, and learning object repositories, making it possible that the IPA can share educational materials with the students. As previously mentioned, this system allows parallel search in different repositories, and so reducing the response time. Moreover, this design presents high scalability since new metadata schemata can be easily integrated. Table 1 shows some of the possible knowledge repositories that our IPA could integrate.

**Table 1.** Characteristics of some semantic and general Learning Objects Repositories

| Name | Description |
|------|-------------|
| YAGO[1] | YAGO is a huge semantic knowledge base. Currently, YAGO knows more than 2 million entities and 20 million facts about these entities. Unlike many other automatically assembled knowledge bases, YAGO has a manually confirmed accuracy of 95%. |
| DBPedia[2] | DBpedia is a community effort to extract structured information from Wikipedia and to make this information available on theWeb. Dbpedia allows users to ask sophisticated queries against Wikipedia, and to link other data sets on the Web to Wikipedia data. The DBpedia knowledge base currently describes more than 3.4 million things, out of which 1.5 million are classified in a consistent Ontology. |
| FreeBase[3] | Freebase is an open, Creative Commons licensed repository of structured data of more than 12 million entities. Freebase is also a community of thousands of people, working together to improve Freebase's data. |
| Connexions[4] | Connexions is an environment for collaboratively developing, freely sharing, and rapidly publishing scholarly content on the Web. Its Content Commons contains educational materials for everyone (from children to college students and professionals) organized in small modules that are easily connected into larger collections or courses. All content is free to use and reuse under the Creative Commons license. It contains 16752 modules. |
| MERLOT[5] | MERLOT is a free and open online community of resources designed primarily for faculty, staff and students of higher education from around the world to share their learning materials and pedagogy. The MERLOT repository includes learning materials, but assignments, comments, personal collections and Content Builder web pages. |
| MIT OCW[6] | MIT OpenCourseWare (OCW) is a web-based publication of virtually all MIT course content (undergraduate and graduate subjects). MIT OpenCourseWare averages 1 million visits each month. |

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[1] http://www.mpi-inf.mpg.de/yago-naga/yago/

[2] http://dbpedia.org/

[3] http://www.freebase.com/

[4] http://cnx.org/

[5] http://www.merlot.org/

[6] http://ocw.mit.edu/

## 3.2 Association Area

This area will merge the results obtained in the Rational Area, making the appropriate associations and decision-making.

The traditional information organization has been always focused on documents, folders, and files. However, the Semantic Web which adds modular, and reusable knowledge resources, is difficult to comprehend by the end user due to the complex structure of knowledge contained in semantic repositories and learning object collections. Humans do not usually look for a certain document or folder, instead they look for information about a particular subject that they are interested in. According to this, we suggest for this area a subject-centric approach, in which information should be organized by subjects, as users typically think.

To implement this area we planned to use a context-aware adaptive system which can adapt its behavior depending on the different user requirements in every moment. The different knowledge resources managed by the IPA (i.e., Knowledge Bases, Learning Objects Repositories, and Commonsense Knowledge Base) can be searched in parallel, but the results must be correctly merged to obtain the most suitable answer depending on the context. In this way, the IPA could assign different weights to the available results obtained from the knowledge resources. In the future we want to test some state-of-the-art artificial intelligence algorithms to find the most suitable to be used by IPAs for educational purposes. Therefore, we argue that our proposal can be used in quite different learning scenarios, such as formal learning, lifelong learning, or vocational learning and training.

## 3.3 Commonsense Area

As previously mentioned, our IPA will be provided with knowledge repositories. Since the resources offered by knowledge repositories are commonly limited to formal taxonomic relations or dictionary definitions of lexical items, we think that our system should also integrate commonsense knowledge (i.e., the collection of facts and information that an ordinary person is expected to know).

Thanks to this area, the Mentor IPA will be provided with Commonsense Knowledge. This area will help to analyze and process both the input queries, and the output responses. It will also support the behavioral area to find the most appropriate emotion according to the context. To accomplish this, a resource which captures a wide range of commonsense concepts and relations, and allows commonsense inferences should be integrated. Table 2 shows a comparison of two open Commonsense Knowledge initiatives which could be used in our system.

**Table 2.** Comparison of two open Commonsense Knowledge initiatives

|  | OpenCyc[7] | ConceptNet[8] |
|---|---|---|
| **Generation** | Largely handcrafted | Automatically from OMCS Corpus |
| **Acquisition** | Knowledge Engineers | General Public |
| **Reasoning** | Formalized Logical | Contextual Commonsense |
| **Content** | Mapping text | Real-world texts |

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[7] http://www.opencyc.org/
[8] http://web.media.mit.edu/~hugo/conceptnet/

## 3.4 Behavioral Area

An important issue in developing pedagogical agents is emotion. A pedagogical agent can motivate the student to learn efficiently with an appropriate usage of several emotions.
This area will make it possible to increase the level of realism of the IPA, addressing some of the key drawbacks that the majority of IPAs present (i.e., the lack of realism, emotions, personality and social interactions). Behavioral area should cover facial expressions as well as body language, or more general non-verbal communication, but also interaction patterns with the learners, etc. The IPA will react accordingly the context and the sense of the queries made by students, including facial and vocal expressions of emotion.

The relationship with a user should affect the emotional reactions of the IPA, and its emotional status and mood must be updated with emotional impulses from the environment [10]. For example if the user is saying something bad happened to him and the IPA has positive impressions of the person, the resulting emotion will be sorry for this situation.
Generally, agents exploit two different channels to show their emotions: Visual and aural channels [12]. Before exhibiting an emotion, the agent has to "feel" something, and then he can show his feeling using the aforementioned channels. A pedagogical agent may feel excitement and joy when the learner does well and it can be disappointed when problem-solving progress is less than optimal. Eliciting emotions is much more difficult concern than conveying emotions. For this purpose, the agent has to recognize the facial expression as well as gesture and speech of the user.

## 4. Conclusions

In this paper we present a proposal to add semantic web knowledge to Intelligent Pedagogical Agents. Our proposed Mentor IPA does not simply give out information, it also provides guidance for the learner, and demonstrates competence while simultaneously developing a social relationship to motivate him. Our main objective is to create more intelligent and more human alike Mentor IPAs, enhancing the learning exierience of students in 3D Immersive Virtual Learning Environments.

We believe that integrating an autonomous Mentor IPA merging suitable semantic repositories could mitigate some problems detected in current VLEs, since it will increase the level of realism, reaching a level of interaction similar to face-to-face. Mentor IPAs will also provide intelligent support and guidance to mitigate the "infoglut" (i.e., when a person is overwhelmed by the presence of too much information).
Shifting the information architecture to a subject-centric perspective, means: (i) changing the way that software and interfaces are designed, (ii) deciding whether or not two different objects represent the same subject, and (iii) empowering a new level of interactivity between systems at global scale [11].

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