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Intelligent Pedagogical Agents in Immersive Virtual Learning Environments: A Review

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Abstract - The concept of Intelligent Pedagogical Agents (IPA) has been an important research topic for a long time. IPA is supported by multi-agent systems research derived from AI. IPA provides personalized instruction, increase learner motivation, and act pedagogically on behalf or with the learner. On the other hand, virtual environments add value to the education process by giving new educational possibilities and computational-richness support. Combining both IPA and Virtual environments can make a promising approach for effective computer-aided learning. This paper provides a review on IPA and related topics focusing on a general overview of the topic, gives a detailed review in the application domain of virtual learning environments, and outlines a proposal for a flexible conceptual approach for the flexible application in different learning settings.

I. INTRODUCTION

Several groups of efforts have been made to utilize advancements in computing for human learning. One such group is Intelligent Tutoring Systems (ITS) that tried to exploit machine intelligence to support the learner in a personalized way, [1]. Since ITSs assume that the learner uses computerized support instead of the human instructor, Virtual Characters (Personal Assistants) have been developed to improve interactivity, [2] trying compensate for the lack of the human aspects in that form. But it resulted in discussions of whether e-learning is better than classical methods and that led to the blended learning approaches. In studying the reason for such a debate, the problem of the lack of face-to-face interaction had consequences in motivational aspects. On the hand of advantages, computer-aided-learning tools such as ITSs can support high degrees of individualization not possible in classical classrooms. Such tools were really successful in providing strong individualization to the learner by supporting adaptations to the system based on user models.

Virtual learning environments (VLE) extend ITS by integrating several educational resources to the learner including multimedia learning material, communication tools, recommender systems, and more. In a VLE, learners are not restricted by time or space constraints. 3D Immersive Virtual Learning Environments adds 3D visualization and the ability of the learner to navigate the 3D virtual environment. The learner immerses into the 3D virtual environment being represented in the 3D space as an Avatar. Others learners are also represented by avatars as well. It is possible to meet other people or educators from other countries online, collaborate with them, discover new places instantaneously, or even play educational games. The visualization of the learning space and interacting with other learners (other avatars) give new possibilities of computer-aided learning scenarios not existed before in a game-like environment that opens the door for creativity and imagination to the learner.

Research has highlighted motivational factors from games, visualization and Human-Computer-Interaction aspects that can greatly motivate the nowadays learner named digital native who likes games [3]. This is materialized in a 3D visual learning environment that utilizes virtual world gaming environments. Examples are second life and Sun Wonderland. Those environments give the abilities to other parties to build their own educational places and therefore they evolved as virtual worlds. Taking the example of Second Life, participants have the ability to build new things and create new possibilities and scenarios. As long as it is a guided built by the crowd, then the environment is scalable and has great potential for adding new educational services day after day. Several educational bodies and education researchers have recognized this importance for education purposes and are seriously considering them for learning.

In Immersive Virtual Learning environments, it is expected that the learner will have great flexibility, faced with numerous learning opportunities and therefore requires intelligent support and guidance. This is in addition to the new possibilities of applying new advancements of computing in the new learning environment. The use of Intelligent Pedagogical Agents, IPA resonates with those demands and therefore is investigated. IPA can act as a teacher, learning facilitator, or even a student peer in collaborative settings. The IPA will guide the learner in the virtual environment, explain topics, ask questions, give feedback, help the learner collaborate with others, provide personalized learning support, and act upon the learner in different times and in virtual places. It is particularly vital that the agent acts pedagogically. Investigating the integration of IPA research and new trends in immersive virtual learning environments can have great benefits towards effective computer-aided learning. This is discussed in this paper while we assume that this area is under research.

The paper is organized as follows: Section 2 introduces Intelligent Pedagogical Agents and discusses its functions in learning by providing a literature review on the topic. Section 3 provides literature review on Virtual Learning Environments. Section 4 shows the potential for IPA's adoption in immersive virtual learning environments and proposes a conceptual view. Section 5 gives a conclusion that provides input for our future work of IPA in virtual learning environments and summarizes the vision of using IPA in the immersive VLE.

II. Intelligent Agents for Pedagogical Objectives

The concept of an Intelligent Pedagogical Agent can be viewed from its name as:

- **Agent**. The agent is a software component that can act by itself in the environment based on a goal.
- **Intelligent.** An Intelligent agent applies distributed AI methods to achieve goals. Intelligence can be characterized as the agent's ability to learn from the environment and change the behavior accordingly to achieve the design goals.
- **Pedagogical**: In our context, the intelligent agent should possess pedagogical abilities to achieve educational objectives.

The idea of IPA can be analyzed from two roots. Firstly, it comes from distributed Artificial Intelligence (DAI) where the intelligence is distributed to a group of intelligent entities (agents). Each agent will act and interact with the environment based on individual goals to reach. Secondly, the use of virtual characters in an ITS have been suggested as an effective method to compensate for the lack of face-to-face interaction, [4]. The Microsoft office assistant is a simple example where the user asks questions and the assistant searches for answers or recommends tutorials. In other advanced forms of educational settings, the learner chooses a character which can provide facial expressions. Animated virtual characters that can guide the learner are sometimes named guidebots. TABLE 1 gives examples of commonly used agent characters in literature.

TABLE 1
POPULAR AGENT CHARACTERS IN RESEARCH

Character	Nature	Reference / comments
Herman the Bug	Virtual character that teaches student biology	See [4]
Steve	*Intelligent Pedagogical Agent, can demonstrate tasks, offer advice, and answer questions.*	See [8]
Adele	A Case-based reasoning agent	See [8]
Peddy	Virtual animated character agent that can teach, has tools for speech recognition and synthesis	See [9]

The development of further capabilities in virtual characters leading to smarter ones with human-like appearance has led to the notion of embodied agents. TABLE 2 gives the meaning and characteristics of relevant used terms to show how the concept has been used in various forms but for similar goals. Common to all those categories is the character objective of improving affection to compensate for the lack of face-to-face interaction in dealing with the machine by expressing feedback emotions in gestures or through verbal dialogues with the learner. Research has shown the effectiveness of characters in improving this aspect of learning [4], [6]. Research in [6] has further investigated this aspect to show that an agent that exhibits a polite behavior provides a significant improvement on the learning result compared to other ones.

TABLE 2
MEANING AND CHARACTERISTICS OF COMMONLY USED TERMS

Term	Examples	Meaning and Characteristics
Agent		*Autonomous Entity with goal.*
Virtual Character	Herman the bug, Steve	*Has character. An animated form is named Animated virtual character. An HCI term*
Embodied Agent	Microsoft Agent	*Has physical body, Stresses the visual appearance* *Embodied Conversational Agents have conversation abilities. An Artificial Intelligence Term.*
Pedagogical Agent	ADELE	*Stresses pedagogical functions*
Intelligent Agent		*Stresses Intelligence abilities such as learning*
Guidebots	Steve, [8]	*Stresses guidance functions to stimulate and encourage learning*
Avatar	Second Life for example	*Incarnation of the user in the virtual environment.* *Is a selected character by the user, mainly used in 3D Virtual Environments, to emphasize personal preferences. Guided by user.*
Intelligent Pedagogical Agents	Work in [6]	*Combines different abilities including intelligence and Pedagogical orientation. Autonomous (not directly guided by user)*

In literature, the concept of Intelligent Pedagogical Agents (IPA) provides more advanced forms than just characters. In the research work of [1], a pedagogical agent has been used to detect and interact with the learner in suitable times such as confusion and indecision to resolve difficulties and increase motivation. The learner's eye gaze has been used as input for a Bayesian network for the required reasoning. In a related aspect of increasing interaction with the learner, the work in [5] tries to improve the interactions between the computer and the learner by means of animated pedagogical agents. This work tries to solve the problem of interaction expectation with the pedagogical agent by means of social intelligence tactics.

IPA can have a significant impact on increasing the learner motivation. This is suggested in an early study conducted on an early IPA; Herman the bug, [4], on 100 middle school students. The study concluded that *"well crafted lifelike agents have an exceptionally positive impact on students. Students perceived the agents as being very helpful, credible, and entertaining."* [4].

IPAs combine different characteristics including artificial intelligence capabilities to enrich the learning environment. For example, the work in [7] employs case-based reasoning techniques to tutoring. An IPA in this research work reads from a database of cases and adapts prior cases to reuse them in tutoring medical students. The IPA in the same work [7] had the following properties: Domain-specific knowledge, Autonomy, Communicability, learning, reactivity and pro-activity, social skills, customization, and learning abilities. It is interesting to have prior teaching strategies re-used. One important theme of research in Computer-Aided learning is the role of personalization (individualization) based on building and capturing user models. Agents have been also used in conjunction with the user models.

Another aspect of improving learner interaction with the learning environment is through creating dialogues with the learner to improve learning situations, provide guidance, resolve difficulties, and improve motivation. Intuitively this can improve learning results as a result of handling different types of learning styles such as verbal-linguistic learners as suggested by the theory of multiple intelligences [10]. Intelligent agents gain pedagogical capabilities if the agent can provide narrations or adaptive conversations with the learner. An early publication in 1999, [11] provided insights into Narrative-Centered Learning Environments by the use of IPA from Narrative Intelligence (AI). It outlines what computer generated narration (by IPA) can contribute to effective learning. Several research efforts followed that to add narrative functions to learning environments, by the aid of agent intelligence. For example, [12] suggests simple personalized (directed) instructional narratives to the learner that can provide instructional value and save class time. This is accomplished by the use of scripted IPA. In that work, different narratives are stored in a database and contextually retrieved on demand during the learning discourse.

III. Immersive and 3D Virtual Learning Environments

What is a virtual learning environment, VLE? What are its characteristics? And what distinguishes it from other environments? A clear view of VLEs that clarifies this issue and provide insights into the design of the VLE can be found in [13]. This work developed 7 characteristics to the VLE, [13].

TABLE 3
"WHAT IS SPECIFIC TO VIRTUAL LEARNING ENVIRONMENTS?" [13]

1. The information space has been designed.
2. Educational interactions occur in the environment, turning spaces into places.
3. The information/social space is explicitly represented. The representation varies from text to 3D immersive worlds.
4. Students are not only active, but also actors. They co-construct the virtual space.
5. Virtual learning environments are not restricted to distance education. They also enrich classroom activities.
6. Virtual learning environments integrate heterogeneous technologies and multiple pedagogical approaches.
7. Most virtual environments overlap with physical environments.

In order to further assess added pedagogical values of Virtual Learning Environments, once can consider it in comparison with Intelligent Tutoring Systems. ITS's characteristic is the removal of human intervention by the use of Artificial Intelligence methods. While Intelligent Tutoring Systems intended to provide pedagogical functions through personalization, sequencing, and others, their direct benefits were a focus on individual uses as direct consequences of the removal of the human tutor. But so far, they lacked the rich 3D visualization aspects that are available in recent 3D virtual learning environments. Furthermore, VLE provides more collaboration and exploration-based learning opportunities and can be much more open and flexible than the individualistic ITS. An Intelligent Agent can roam across several domains to search for resources, collaborate with other peers, or learn from others' experiences. This was not a design factor in an individual ITS.

In the virtual environment, the user (learner) has more control on his/her experiences and is more of an actor. Therefore, it is more directed towards learner-centered learning, and hence we expect greater need for individualization services towards learners as actors.

Immersive 3D Virtual environments have two modes of operation. First, the user (learner) immerses into the 3D environment where he/she will be able to see experiences, have lectures, and work with 3D learning objects alone or in collaboration with others. The learner will perceive other potential collaborators or users of the virtual environment with a representation (a virtual character for example), named an Avatar. In traditional ITS, the character is assigned to a tutor only. But now we can expect (and agreeing to vision of [13], point 4 of TABLE 3) that each participant has an actor representation in the virtual environment.

Benefits of Immersive Virtual Learning Environments to learning include the flexibility relevant to removing time and distance barriers to collaborate with others visually. For example, a physics experiment can be conducted with visualization and simulation of equipment and with participants who are remotely located but are interacting synchronously or asynchronously by the aid of the immersion in the VLE, see [16].

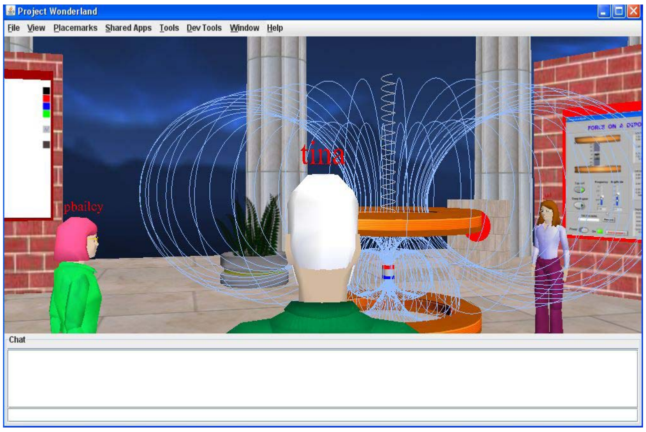

Fig. 1. "Close-up view of the 'Force on a Dipole' Experiment in Wonderland", from [16].

Another strong value of the Immersive Virtual Learning Environment, according to [19] is its ability, through the rich visualization, to provide authentic learning experiences (focusing on real world experiences). Authentic learning experiences are not easily available in learning institutions; take a nuclear reactor for example. As virtual environments are simulation places, they can provide both imaginary scenarios and simulations of real world scenarios that are rare (What to do in an earthquake or in a battle). Both of them are valuable to the learning process.

The Social aspects of learning can also be improved with Immersive Virtual Environments. Since the learner can immerse into the environment to meet other people, then the Immersive VLE can outperform ITS in terms of collaborative learning which has significant importance nowadays. 3D virtual worlds such as Second Life, Sun Wonderland, and EDUSIM have been used for educational purposes as VLE, see [20]. And therefore, they provide examples of benefits of innovative collaborative learning scenarios, see also work in [14][15]. Furthermore, universities have been trying to adopt new learning experiences by existing in virtual worlds. For example, Harvard Law School conducts lectures in the Berkman's island of second life.

Recently, education research has targeted the fast growing 3D immersive environment for education purposes. While these environments have the above mentioned benefits, and also the wide attention gathering, they also have the game-playing orientation.

IV. IPA Roles in the Immersive VLE

When the virtual environment becomes increasingly bigger with lots of available places to visit and learn from, pedagogical scenarios are pervasive, guidance is needed by an agent to aid the leaner to find places, people, or avatars relevant to the educational goals. An offline service of the immersive environments is that learners may interact with others who are offline if their agents' representation have intelligence capabilities, for example as a virtual tutor if the instructor of the virtual university is away or as a student collaborator otherwise. This can be achieved by the use of Intelligent Pedagogical Agents in the immersive VLE. IPA can provide intelligent guidance for the learner in the immersive VLE. Furthermore, given the potential number of collaborators in the virtual learning environment, and with the possible individualization abilities for pedagogical objectives [10], support is needed to automatically finding effective peers to collaborate with. This support can be given by an IPA that understands the learner abilities and the associated learning goals to interact with other IPA available in the VLE.

With the above mentioned scenarios, the use of avatar to only provide visual representations and characters although is great for improving motivation support, it cannot be enough. Avatar is not enough in doing so since the Avatar actions are guided by the person (user). Instead a pedagogical pro-active and autonomous agent is needed to assist or do other pedagogical actions with or on behalf of the learner in the environment. It requires further intelligence inspired from ITS but is generalized to all actors (learners, visitors, tutors, etc) in VLE to have greater intelligence abilities that can improve pedagogical functions and act intelligently on behalf or with the learner to achieve goals. Therefore we strongly propose integrating the IPA concepts in the immersive VLE.

IPA roles in the Immersive virtual environment can be summarized to be

- Providing visual representation of learner, such as Avatar
- Provide intelligent visual appearance such as virtual characters. This will improve interactivity and improve learner motivation.
- Provide narrative and dialogue functions that provide increased engagement and immersion in the environment. IPA narration has proved to improve the sense of presence in the environment, [25]
- Intelligent navigation in the environment for pedagogical objectives
- Provide pedagogical services to the learner
- Serve collaborative learning functions, [17]

Architectures and Design Perspectives of IPAs in Immersive Virtual Learning Environments

The use of IPA in Immersive virtual environments, as shown above is important to have effective pedagogy. The blend of IPA in VLE should be done in a way that integrates with prior research on individualized ITS concepts. It should also be done in a way that encourages reusability of pedagogical objects, models, and methods in order to achieve a suitable scalability result for the learning community in large in the VLE. With this, the Virtual Learning Environment can grow as a result of contributions and this growing is needed to increase services and to materialize new pedagogical methods. According to TABLE 3, the information space of the virtual environment has to be designed. A conceptual view of it should consider the following:

- Personalization and user models
- Representation of pedagogical objectives

- Intelligent pedagogical agent functions
- Agent societies
- Agent Standards and AI abilities
- Agent Conversational Abilities to engage the learner, keep his attention and provide verbal guidance
- Efficient pedagogical utilization of 3D visual and immersion capabilities available in the environment.
- Vision for the future of Virtual environments
- Collaboration requirements
- Standards for the virtual environments and avatars
- Other educational standards such as SCORM
- Scalability, reusability, and other software architecture success factors

Several research efforts have investigated related IPA in VLE from relevant architectural/technological aspects, [21][22][23][24][25][26][12]. Research work in [21] provided a method of integrating and reusing a virtual character in a VLE through dividing the problem complexity to modeling the different Virtual human aspects (Geometric, kinematic, physical, behavioral, and cognitive). It also proposed the Virtual Human Architecture that is relevant to the virtual human behavior and how to integrate it to the X3D platform [27] through the Virtual Reality Modeling Language (VRML) which is an XML-like language. In order to achieve improvement and have richness in the 3D VLE, scalability must occur through the distribution of efforts among learning content providers and integration can only occur through standardization. The same effort provided the required context focusing on visualizations. However it did not consider other standards such as SCORM and only focused on behavioral issues of the virtual character but not the environment pedagogical services while assuming a singular virtual human.

Providing a human-like dialogue (while it can be integrated to the behavior model) was not considered as well. A strong value of IPA in VLE comes from its ability to provide rich support for collaborative learning, [17]. The work in [22] not only considers the collaborative learning potential of the VLE but also integrates the conversational aspects of the IPA as a major design factor. That work stresses the non one-to-one interaction but multiparty dialogues by multi IPAs thus achieving social and collaborative learning benefits. A four layer agent design is proposed to include conversation abilities. Furthermore, pedagogical functions are considered. The contribution of this work focused on the agent multiparty dialogues focusing on social and collaborative aspects and inclusion of pedagogical intelligence, but not the supporting architectures of scalability and reuse in the environment.

The work in [23] presented an architecture of INVITE that consists of content management module; considering LOM standard, virtual world's platform module that uses 3D VRML standard, agent module that uses a multi-agent environment supporting VRML, translation module, 3D world's module, avatar module, and a streaming video module. The work focused on the importance of reuse of learning content.

Several efforts focused on building narrative abilities in agents through narration and spoken dialogue systems [25][26][12]. BASILICA is an event driven software architecture that enables creating agents in virtual environments with conversational abilities [24]. The conversations between the agent and the learner are limited by an intervention strategy that avoids unwanted interventions by agents. In this work, the CycleTalk agent [24] was integrated in SecondLife as a Virtual Environment. The CycleTalk Agent consists of Filters for different events and Actors. Once the agent is implemented, it can be re-used.

V. CONCLUSION

One major concern of e-learning systems over traditional methods is the lack of face-to-face interactions and consequently motivational concerns occur. IPA research, as shown in this paper tries to compensate this by increasing intelligent interaction with the learner. Also, the recent use of 3D immersive virtual environments has shown effectiveness in improving the motivation towards learning by using such environments. Therefore, combining both approaches can provide significant contributions to solve the mentioned deficiency. It can also create new scenarios of pedagogical intelligence in the new educational paradigm.

Intelligent Pedagogical Agents research have not yet exploited the potential of the use of DAI (intelligent agents) capabilities in the VLE. Most of the work on pedagogical agents has focused on the visual appearance and interface with the learner as a character. However, there are lots of potential of intelligent agents capabilities, especially of AI, Social abilities, intelligent resource location, negotiation, and social abilities that can bring several useful learning scenarios for collaboration in the virtual learning environment.

The scalability gain exemplified in knowledge creation of the social Web and in visual objects in the great promising 3D virtual environment should be also exploited in creating (in a similar manner) reusable pedagogic methods in the virtual environments by means of intelligent pedagogical agents and their associated societies. Further unified efforts are needed, in a wider scale, working on standardization and reusability to give a wide infrastructure to scale pedagogy in the VLE utilizing innovations in IPA.

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