3D Animated Agent for Tutoring Based on WebGL

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Abstract

The goal of the work presented in this paper is to develop a 3D web based online tutoring system that enhances the motivation and cognitive development of students. To achieve this, a virtual assistant will be integrated to the e-learning platform; this 3D modeled e-tutor will evaluate each student individually, it will react to their learning progress by empathetic gestures and it will guide them through the lectures according to their personal needs. The accomplishment of these tasks will imply a thorough study of the latest techniques on artificial intelligence, multi-agent architectures and their representation by means of 3D emotional avatars.

CR Categories: I.2.11 [Distributed Artificial Intelligence]: Intelligent agents; I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Animation; I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual reality; I.3.8 [Computer Graphics]: Applications;

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1 Introduction

The use of online learning or e-learning has increased significantly in the past years and it is expected to keep growing in the future. According to the latest survey by Ambient Insight Research [Adkins 2013] the aggregate growth rate for self-paced e-learning products and services expected for the next five year period (2011-2016) is 7.6%. Distance learning offers a series of benefits that traditional learning does not, for example in terms of mobility, affordability or flexibility e-learning happens to be much more suitable for nowadays lifestyle, moreover this technology has enabled increasingly dynamic and engaging learning experiences.

Many studies have been held to research the benefits of online learning, but this paper focuses on the benefits that the introduction of virtual agents in e-learning platforms may have in the cognitive process of students. This work introduces an animated agent with real-time humanlike responses to students' interaction, by means of non-verbal gestures, natural behaviour and verbal communication; this artificial intelligence will increase the students' motivation and will engage them to the lectures.

Studies like [Bloom 1984] demonstrated the effectiveness of one-on-one human tutoring against other methods of teaching, and [Lepper et al. 1993], defended the idea that education could be globally improved if every student was provided with a personal tutor. This is something almost impossible to achieve in traditional education but it is not so in online learning. Intelligent animated agents represent a new generation of human computer interface (HCI) design. Animated pedagogical agents [André et al. 1997] [Shaw et al. 1999] [Lester and Stone 1997] [Piesk and Trogermann 1998] [Schöch V and G 1998] are life-like autonomous agents that facilitate human learning by interacting with learners and make computer-based learning more engaging and effective [Johnson 1998].

However, most commonly used e-learning systems are not interoperable with other platforms such as Learning Management Systems, web-based virtual world platforms, Virtual Reality learning systems or simulators; this causes several compatibility problems and limits their use. The work presented in this paper solves this issue as it is entirely web based so it will run in any compatible browser. Meaning that it will run in any browser supporting WebGL [Leung and Salga 2010] technology as it is the Application Programming Interface (API) chosen in this work to render the 3D agent via web. WebGL is based on OpenGL, which is a widely used open source 3D graphics standard. Nowadays, most common browsers support this technology; Google Chrome, Mozilla Firefox, Apple Safari or Opera.

This paper is organized as follows; Section 2 analyzes the related work carried out in the last years concerning animated agents in virtual reality systems, Section 3 describes the architecture followed to accomplish the goals of this work, Section 4 shows validation results from the platform. The final section is about conclusions and future work.

2 Related work

The purpose of this work is to develop a virtual agent which will fulfill the role of a virtual tutor in various web-based e-learning systems. Such virtual tutor must react to the students' needs as if it were a real tutor, so this virtual agent must be provided with sufficient artificial intelligence to react in an autonomous way and natural behaviour to give the impression of interacting with a real teacher.

Research has outlined a number of desirable attributes for this kind of pedagogical agents [Ahmed 2005]. The agent must be an autonomous character and it must be able to perform almost every action without the direct intervention of other agents. Moreover, it must react to changes in the environment and respond to them over a certain period of time.

Many studies [Dehn and Van Mulken 2000] [Johnson et al. 2000] [Moundridou and Virvou 2002] [Baylor and Ryu 2003] have found that rendering agents with lifelike features, such as facial expressions, deictic gestures and body movements may rise the so called persona effect. A persona effect is a result of anthropomorphism derived from believing that the agent is real and authentic [Van Mulken et al. 1998] [Baylor and Ebbers 2003]. The persona effect shows that the presence of a lifelike character in an interactive learning environment can have a strong positive effect on students' perception of their learning experience [Lester et al. 1997] .

Providing natural behaviour skills to virtual agents is also a

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widely studied issue. However, defining natural behaviour is not an easy task. The literature and theory of affective computing imply several conditions for synthesized motion to appear natural [Abrilian et al. 2005]. Speed of interaction and emotion/speech-correlated believable body motion are among the most important functionalities [Mlakar and Rojc 2011]. Rieger [Rieger et al. 2003] developed a series of rules in order to increase the acceptance of virtual agents in Human-Computer Communication and established a correlation table between the message to rely and the emotion to show.

As far as the agent's appearance is concerned, research does not give a clear answer as to which design is best, whether to portray the agent with a real human look or with an iconic feature. For example, [Nass et al. 2000] proposed that the appearance of agents should be made to resemble that of the learners. However, such view is opposed by [Buisine and Martin 2007], who cited Kohar's recommendation [Kohar and Ginn 1997]; dramatized characters can display more exaggerated emotions than realistic humanlike agents.

Steve [Johnson and Rickel 1997] was one of the first pedagogical agents capable of expressing emotions; it was designed as a stereoscopic 3D character that cohabited with learners, it has been applied to naval training tasks. However, Steve was originally designed to operate in immersive virtual environments and not over the Web. Adele [Shaw et al. 1999], was the evolution of Steve into the World Wide Web, Adele's design was based on an autonomous agent paradigm able to use facial expressions and react to students' actions. More than a decade has passed since these works were presented, technology has evolved a lot since then and the internet has become accessible to almost everyone.

D'Mello's study [D'mello and Graesser 2012] presents two interactive intelligent systems that promote learning and engagement thanks to an animated teacher. These studies have motivated further work such as AutoTutor-Lite which is a simpler version of the former but keeps the most important features. AutoTutor-Lite is optimized for web-based learning environments; it uses a lightweight semantic engine that can be implemented as a small plug-in of flash movie that works on the learner's computer. It is web-served so the user can interact with AutoTutor-Lite in the web, introduce content and receive automatic tutoring back [Hu 2011].

More recently, [Benin et al. 2012] presented the implementation of a WebGL talking head for compatible browsers and iOS mobile devices based on LUCIA; a three-dimensional animated computer talking head which repeats any input text in six different emotional ways.

Although this system meets many of the requirements desired in our work (web-based, no additional plug-ins required, 3D modeled character) it does not interact with the users, neither reacts to their behaviour nor guide them throughout the learning process. The following section describes the architecture followed to achieve the goals of this work.

3 Architecture

This section introduces the architecture of the Animated Agent Engine implemented to work on e-learning platforms. The goal of this work is to develop a humanlike character to guide students in their learning process and to encourage them by showing emotional feedback. To accomplish this a virtual character has been designed following several rules regarding appearance and natural behaviour.

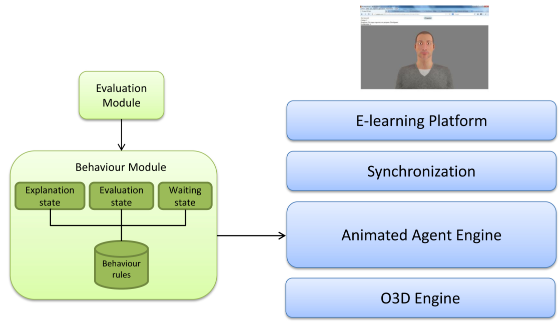

Figure 1: *Animated Agent Engine Architecture.*

The following sections describe the most relevant modules of the architecture shown in Figure 1.

3.1 Behaviour Module

In order to make the agent's behaviour more natural the agent will be able to perform several hand gestures. The scientific community has established four type of hand gestures [Cassell et al. 1994]:

- Iconic: or illustrators, they are descriptive gestures often used to illustrate speech.
- Metaphoric: or representational gestures, represent an abstract feature concurrently spoken about.
- Deictic: indicate a point in the space.
- Beats: small formless waves of the hand that occur to emphasize words.

Thus, the agent will be able to point out elements in the screen or perform spontaneous gestures with the hands. The agent will also vary the speed in which he performs these gestures depending on his mood [Carretero et al. 2012]. When people are sad their movements and gestures tend to be slower than when they are happy, in this case they execute movements in a quicker and energetic way.

The animated agent will also be able to reproduce facial expressions. Based on Ekman's six universal emotions [Ekman and Friesen 1981] the Animated Agent Engine is able to show the following facial expressions: happiness, sadness, surprise, anger and neutral expression. Disgust and fear have not been taken into account as they might lead to the opposite reaction desired from the student, the aim of this animated character is to stimulate the learner and these emotions may have a negative influence. Figure 2 shows happiness, surprise, anger and sadness from the agent in response to questions made by the student.

The role of the agent will be divided into three states:

- Explanation state: the animated character will introduce the lecture to student and will explain any necessary information. To make this explanation more appealing to the learner the agent will perform several natural behaviour movements, such as, iconic or deictic gestures. The behaviour in this stage can be edited by the real tutor who prepares the lessons. For this purpose, an authoring tool to edit the agents behaviour is provided.
- Evaluation state: the virtual agent reacts depending on the student's responses. This state is influenced by the Evaluation Module.

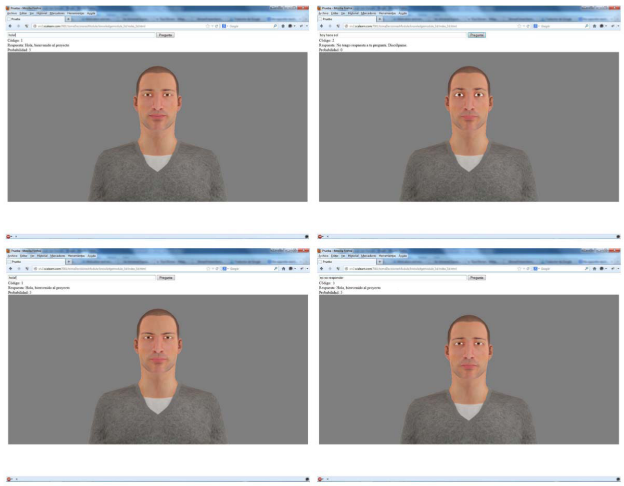

Figure 2: *Emotions from the Animated Agent reacting to student's input.*

- Waiting state: this state is executed when the virtual agent is neither explaining nor evaluating. The e-learning platform will provide several content in order to complete the course; text, video or audio may appear to clarify concepts, in this case the agent will perform waiting state movements. Humans do not stand hieratic when waiting for something to happen, we move our head, eyes, balance our body. The Animated Agent Engine takes this factor into account and allows the virtual agent to perform this kind of waiting movements when necessary.

These states and their behaviour rules influence the Animated Agent Engine and indicate how the virtual agent must react.

As mentioned before, in the Explanation state a real tutor should edit the virtual agent's behaviour so that the agent acts as similar as a real tutor would. In addition to the authoring tool provided for this purpose a Behavioural rule database will be used.

Most of these rules are related to hand and arm movements or facial expressions, but some are also related to gaze, blinking or posture.

The Evaluation Module will animate the virtual agent depending on the learner's interaction, for example, the agent will express happiness if the student answers correctly, it will shake his head when the answer is incorrect or it will appear sad if the student fails an exam. The Waiting state will use behavioural rules related to body posture, head movements, gaze, etc. For example, the virtual agent will cross his arms or will balance his body randomly in order to emulate human natural behaviour when standing for long periods of time.

These rules intend to make the virtual agent more lively and humanlike by emulating the behaviour of real people. Following the system logic, they will be executed randomly so that they do not result repetitive.

3.2 Evaluation Module

The animations reacting to the student's learning progress will be executed in the evaluation state. This state is meant to accompany the learner throughout the course so it will react in real-time to the learner's input.

The Evaluation Module will keep track of each student along the course in order to give personalized feedback to each individual. When the student types a question into the web browser, this input is evaluated taking into account several aspects and the logic inside the module determines the appropriate code. This code is used as the input for the Agent Module and depending on its value a certain emotion or movement is performed by the virtual agent.

As mentioned in the previous section, some behaviour rules have been defined for this state. In the case of facial expressions, when the student types a question and the returning code indicates the system has the answer, the virtual agent will express happiness, if the code indicates that the system does not understand the question, the agent will appear surprised or confused. The virtual agent will also execute different movements when evaluating the student; if the answer is correct it will rise up his thumb, if the answer is incorrect he will shake his head or hand (Figure 3).

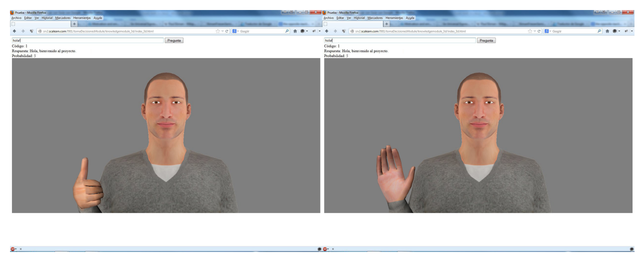

Figure 3: *Approval and Disapproval gestures.*

Furthermore, the Evaluation Module will save information regarding several aspects such as; the knowledge level of the student, the number of times a student enters a course, the frequency of interaction with the platform, the mistakes a student makes before finding the correct answer, etc. All this information will be stored in a database and will be analyzed by the Evaluation Module. Depending on the result of this evaluation the Animated Agent Engine will perform different actions. Figure 4 shows an example of this logic.

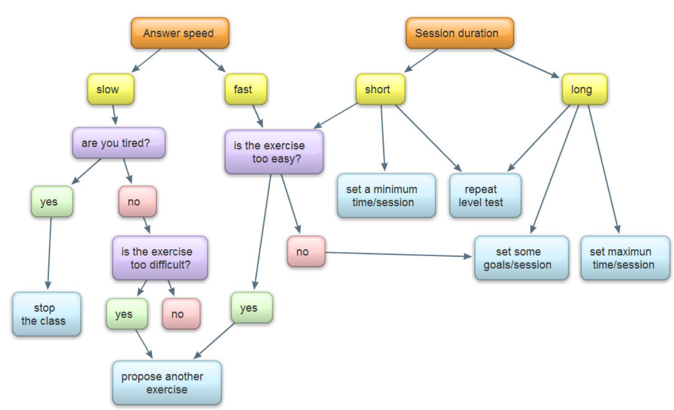

Figure 4: *Example of the Evaluation Module logic.*

The student's interaction with the e-learning platform can be analyzed in different ways, for example, controlling the speed in which the student answers questions or the duration of each session. If a student takes too long to answer a question, the Evaluation Module will send an impulse to the agent and it will react to this delay by asking some questions to the student; "is the exercise too difficult?", "are you tired?". The duration of each session can also be verified in order to evaluate the student's learning progress. Very short or long sessions might suggest the exercise does not match the student's knowledge level, in this case the virtual agent will suggest the student different exercises or will repeat the test to determine the students level.

This kind of communication makes the students feel accompanied and they appreciate the concern showed by the virtual agent. This attention on the one hand makes them feel that their work is being valued and on the other hand infers some pressure on them, so it is more difficult for them to abandon the course.

3.3 Animated Agent Engine

According to McCloud [McCloud 1994] individuals see themselves as iconic images but see others in a more detailed form, that is, as realistic images. Gulz and Haake [Gulz and Haake 2006] extended this idea to the role of animated pedagogical agents and stated that if the agent is acting as a teacher, the student will see it as "the other person" and therefore it is better to represent it in a human form. The agent of this work has been designed following these ideas; it will clearly perform the role of a teacher and not a classmate so it will appear in a realistic way.

As presented in the introduction, WebGL technology has been selected to render the 3D virtual agent into any compatible browser without the use of additional plug-ins. The Animated Agent Engine is composed by several modules developed using JavaScript programming language and following all the HTML5 and Web3D standards. These modules have been developed as an abstraction layer over O3D[1] engine which has been selected amongst other engines (GLGE, x3dom, etc.) for its benefits, as it is not a very high level API it allows great flexibility when developing new features.

The Agent Module is in charge of setting the emotions and the natural behaviour to the virtual character depending on the input received from the *Evaluation Module* and the *Behaviour rules*.

The animations executed in the platform can be either programmatically implemented or predefined by the designer in the Collada file. In this work the last option has been used, the animations are predefined in a timeline and they are coded sequentially following the next cycle; neutral expression - animation - neutral expression.

Each coded expression is reproduced when the animation engine decides which animation to launch. When several animations have to be reproduced the transition between one animation and another happens by reverting the timeline to the initial neutral state and then executing the transition from that neutral state to the following animation.

The realistic perception of the human body is mainly due to the complexity of its structure. The numerous details that compound the facial and body gestures result from simultaneous movements of muscles, bones, tendons and other fibers. This complex system cannot be reproduced as it occurs in nature when designing virtual agents in 3D virtual worlds, as muscles, fibers or tendons are not available tools. These human characteristics must be reproduced with the technology offered by software, namely, bones, morphing and bezier curves. The use of the last is not very common, normally morphing or bones methods are used to deform the geometry mesh.

Between these two possibilities morphing has been discarded, despite it being a much faster resource for modeling, it is limited to the number of variants made for each expression or phoneme. Another problem is that morphing is based on the transformation of a big mass of vertices, this implies having very little control over any modification, so the risk of corrupting the geometry increases with the number of vertices.

The use of bones as modifiers makes the tool compatible with any humanoid agent we want to include. The configuration of a face and a body will be valid for any model we use, and no changes will have to be made per agent as when using morphing, doing it the first time will be enough. With this method not only the designer decides how a face behaves, but leaves the door open to programmatically make adjustments or new representations.

The fact of having a clear hierarchy of the internal structure and the knowledge of the influences between bones, makes the tool very simple for anyone in the team working with the virtual agent.

In order to have greater control over the different expressions, a facial bone structure has been implemented. To achieve this, the movements of the different muscles of the face have been studied and a bone hierarchy has been applied to allow the movements of the facial biomechanical structure.

In the body a simplified structure of the human skeleton has been applied, discarding all the bones that hardly revert in modifications when making the movements required for the application. Some examples of animations that need to be implemented are; walking cycles, sitting down action, arm gestures or head movements.

To configure the face the Facial Definition Parameters of the MPEG-4 standard [Pandzic and Forchheimer 2003] has been use, but some of these points have been adapted to match the criteria required in this work. For example, simplification of the less visible areas, optimization of complex mouth zones, organization of the eyes and eyelids into a hierarchy to obtain mayor control and reduction of adjacent control points (Figure 5).

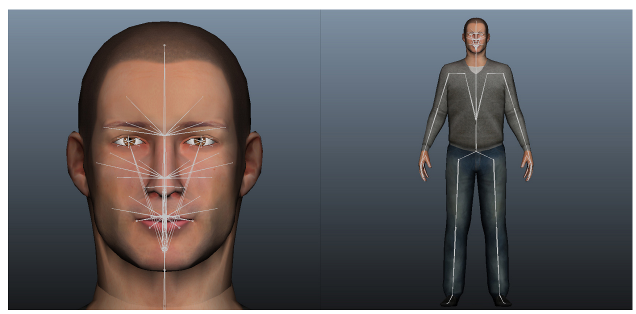

Figure 5: *Face and Body Bone Structure.*

The designer chooses the modifications for each group of bones, when the phonemes and the expressions are correctly defined by animation keyframes, the entire scene is exported in Collada format and it is ready to be loaded into the platform.

However, compared with morphing animations, bones technique implies a performance dropdown that can be particularly meaningful in Web3D environments. Computationally speaking, each vertex has to be weighted by the local transformation matrix of each affecting bone, while in the former method the final position is obtained with a simpler linear interpolation. This fact involves a serious bottleneck in the animation pipeline since the arithmetic engines of JavaScript interpreters are not able to perform the required computations in real-time.

In order to overcome this situation our animation engine implements a hardware skinning algorithm that delegates all bone transformations to the GPU. It has been implemented as a GLSL vertex shader that takes the original mesh and the transformation matrices of the bones as inputs, and calculates the new vertex

[1] `http://code.google.com/p/o3d/`

positions as output. It is worth mentioning that this approach implies that the mesh information that the engine has is no longer related with the actual position of the vertices. This can be a drawback, for instance, in cases where the bounding box of the mesh is needed, like in collision detection or culling operations. Nevertheless, the performance obtained is far greater than the CPU implementation, being able to move in real time complex bone structures.

4 Validation

Although we are still working on the development of the modules that constitute the platform, some of our final users in different applications have seen the animated agent presented in this work and they have all agreed that it is more likeable and engaging than other agents, they state that it seems very natural and humanlike and this favors a more realistic way of interaction.

This validation process has been followed not only to verify the usefulness of the virtual character and its positive effect on learners but also to improve its natural behaviour and facial emotions. Next we mention some of the comments received from the users about our animated agent organized by positive aspects the users stress about the agent and some suggestions they have made in order to improve its behaviour.

Positive aspects:

- Including natural behaviour in the waiting state makes the virtual agent more lively.
- Common gestures such as “good”, “no”, “ok”, etc., give realism to the virtual agent.
- Certain gestures make the virtual agent funny, so the human-computer interaction turns out to be funny.
- The virtual agent’s emotions are easy to recognize.
- Varying the speed in which the virtual agent performs gestures depending on its mood is very interesting.

Suggestions:

- The virtual agent’s movements may end up being too repetitive.
- When the virtual agent is in an explanation stage, it would be convenient to reduce the amount of natural behaviour movements.
- The concatenation of some movements may seem unnatural.
- The virtual agent’s facial expressions should be magnified.

The positive comments suggest that our animated agent results more appealing than non-animated ones. Its natural behaviour improves the human-computer interaction. Integrating a humanlike agent in the platform approaches the users to a real classroom scenario so they react accordingly. The suggestions made by the users have also been very useful and we have taken them into account for future work in order to improve the agent’s behaviour.

5 Conclusions and Future work

A 3D animated agent based on WebGL has been presented in this paper. Thanks to the Animated Agent Engine developed in this work the system is compatible with any web browser supporting WebGL technology, thus it solves the interoperability issues that e-learning systems normally present.

The Evaluation Module implemented in this work provides the animated agent with sufficient artificial intelligence to react to the students interaction in real-time. This logic turns the animated agent into an autonomous agent that needs no exterior intervention to make its decisions.

The idea for future work is to validate the functionality of the global platform in order to confirm the positive effect that the animated character has in real students. We plan to verify that the agent’s natural behaviour and its real-time emotional response to the student’s inputs has a beneficial effect on the student’s learning engagement and final cognitive results.

Although this work has not been tested with real students, we have validated the animated agent with other applications and we have received feedback from users. They all agree the animated agent seems natural and appealing. The suggestions made by the users have been taken into account and we are working to solve them.

We agree that some of the agent’s movements may result too repetitive. In order to resolve this issue we are thinking on adding new movements to the natural behaviour module or including algorithms to modify the original movements. In addition, we plan to change the behaviour rules so that the Animated Agent Engine launches gestures with equal meanings randomly, namely, to disagree with the learner the virtual character will be able to arbitrarily decide whether to shake his head or move his hand.

We have also noticed that natural behaviour movements may sometimes distract the user from the main message, so we are going to modify the behaviour rules so that they focus on the meaning of the message and control sporadic movements.

Finally, to exaggerate the expressiveness of the virtual character the 3D model can be modified, new 3D graphic designs can be developed in order to meet the needs of each user. Nevertheless, this aspect does not require any changes from the Animated Agent Engine.

Two main animations are performed on the facial area: phonemes and expressions. These animations must be well correlated in order to achieve autonomous and natural behaviour from the virtual agent. For this purpose, a weighting of the influence of the vertices of the phonemes with their corresponding expression will be made, so that the agents mood is recognized without losing the mouth posture.

When the work is finished we plan to validate the system with real students in order to evaluate their learning progress and prove whether animated agents enhance the cognitive development.

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References

ABRILIAN, S., DEVILLERS, L., BUISINE, S., AND MARTIN, J.-C. 2005. Emotv1: Annotation of real-life emotions for the specification of multimodal affective interfaces. In *HCI International*.

ADKINS, 2013. The worldwide market for self-paced elearning products and services: 2011-2016 forecast and analysis, January.

AHMED, K. S. 2005. Animated pedagogical agents in web-based intelligent learning environment.

André, E., Rist, T., and Müller, J. 1997. WebPersona: A Life-Like Presentation Agent for Educational Applications on the World-Wide Web. In *Workshop on "Intelligent Educational Systems on the World Wide Web", 8th World Conference of the AIED Society*.

Baylor, A., and Ebbers, S. 2003. The pedagogical agent split-persona effect: When two agents are better than one. In *World Conference on Educational Multimedia, Hypermedia and Telecommunications*, vol. 2003, 459–462.

Baylor, A. L., and Ryu, J. 2003. The effects of image and animation in enhancing pedagogical agent persona. *Journal of Educational Computing Research 28*, 4, 373–394.

Benin, A., Leone, G. R., and Cosi, P. 2012. A 3d talking head for mobile devices based on unofficial ios webgl support. In *Proceedings of the 17th International Conference on 3D Web Technology*, ACM, 117–120.

Bloom, B. S. 1984. The 2 sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. *Educational Researcher 13*, 6, 4–16.

Buisine, S., and Martin, J.-C. 2007. The effects of speech–gesture cooperation in animated agents behavior in multimedia presentations. *Interacting with Computers 19*, 4, 484–493.

Carretero, M., Ardanza, A., García, S., Díez, H., Oyarzun, D., and Ruiz, N. 2012. Improving gestural communication in virtual characters. In *Proceedings of the 7th international conference on Articulated Motion and Deformable Objects*, Springer-Verlag, Berlin, Heidelberg, AMDO'12, 69–81.

Cassell, J., Pelachaud, C., Badler, N., Steedman, M., Achorn, B., Becket, T., Douville, B., Prevost, S., and Stone, M. 1994. Animated conversation: rule-based generation of facial expression, gesture & spoken intonation for multiple conversational agents. In *Proceedings of the 21st annual conference on Computer graphics and interactive techniques*, ACM, 413–420.

Dehn, D. M., and Van Mulken, S. 2000. The impact of animated interface agents: a review of empirical research. *International Journal of Human-Computer Studies 52*, 1, 1–22.

D'mello, S., and Graesser, A. 2012. Autotutor and affective autotutor: Learning by talking with cognitively and emotionally intelligent computers that talk back. *ACM Transactions on Interactive Intelligent Systems (TiiS) 2*, 4, 23.

Ekman, P., and Friesen, W. V. 1981. The repertoire of nonverbal behavior: Categories, origins, usage, and coding. *Nonverbal communication, interaction, and gesture*, 57–106.

Gulz, A., and Haake, M. 2006. Design of animated pedagogical agentsa look at their look. *International Journal of Human-Computer Studies 64*, 4, 322–339.

Hu, X. 2011. Autotutor lite (interactive event).

Johnson, W. L., and Rickel, J. 1997. Steve: An animated pedagogical agent for procedural training in virtual environments. *ACM SIGART Bulletin 8*, 1-4, 16–21.

Johnson, W. L., Rickel, J. W., and Lester, J. C. 2000. Animated pedagogical agents: Face-to-face interaction in interactive learning environments. *International Journal of Artificial intelligence in education 11*, 1, 47–78.

Johnson, W. L. 1998. Pedagogical agents. In *Proceedings of ICCE98*, 13–22.

Kohar, H., and Ginn, I. 1997. Mediators: guides through online tv services. In *CHI'97 extended abstracts on Human factors in computing systems: looking to the future*, ACM, 38–39.

Lepper, M. R., Woolverton, M., Mumme, D. L., and Gurtner, J. L. 1993. Motivational techniques of expert human tutors: Lessons for the design of computer-based tutors. In *Computers as Cognitive Tools*, S. P. Lajoie and S. J. Derry, Eds. Lawrence Erlbaum Associates, 75–105.

Lester, J. C., and Stone, B. A. 1997. Increasing believability in animated pedagogical agents. In *Proceedings of the first international conference on Autonomous agents*, ACM, New York, NY, USA, AGENTS '97, 16–21.

Lester, J. C., Converse, S. A., Kahler, S. E., Barlow, S. T., Stone, B. A., and Bhogal, R. S. 1997. The persona effect: affective impact of animated pedagogical agents. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, ACM, 359–366.

Leung, C., and Salga, A. 2010. Enabling webgl. In *Proceedings of the 19th international conference on World wide web*, ACM, 1369–1370.

McCloud, S. 1994. *Understanding comics*. William Morrow Paperbacks.

Mlakar, I., and Rojc, M. 2011. Towards ecas animation of expressive complex behaviour. *Analysis of Verbal and Nonverbal Communication and Enactment. The Processing Issues*, 185–198.

Moundridou, M., and Virvou, M. 2002. Evaluating the persona effect of an interface agent in a tutoring system. *Journal of Computer Assisted Learning 18*, 3, 253–261.

Nass, C., Isbister, K., and Lee, E.-J. 2000. Truth is beauty: Researching embodied conversational agents. *Embodied conversational agents*, 374–402.

Pandzic, I. S., and Forchheimer, R., Eds. 2003. *MPEG-4 Facial Animation: The Standard, Implementation and Applications*. John Wiley & Sons, Inc., New York, NY, USA.

Piesk, and Trogermann. 1998. Presenting educational contents in nonlinear narrative structures by conventional virtual actors. In *Proceedings of ED-MEDIA98*, 1885–1888.

Rieger, T., et al. 2003. Avatar gestures. *Journal of WSCG 2003 11*, 379–386.

Schöch V, S. M., and G, W. 1998. adi an empirical evaluation of a tutoring agent. In *Proceedings of ED-MEDIA98*, 1271–1282.

Shaw, E., Johnson, W. L., and Ganeshan, R. 1999. Pedagogical agents on the web. In *Proceedings of the third annual conference on Autonomous Agents*, ACM, 283–290.

Van Mulken, S., André, E., and Müller, J. 1998. The persona effect: How substantial is it? *People and Computers*, 53–66.