ELEIN: E-learning with 3D interactive emotional agents

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Abstract. The ELEIN system reached two important issues for e-Learning: the presence of virtual tutors and the importance of emotions in the learning process. In this research we deal with the presence by means of using an expressive 3D animated avatar. Regarding the emotions in the learning process, we differentiate between static and dynamic generation of emotions. In the paper, we specially detailed the development of the dynamic generation, which is achieved by means of the implementation of a computational emotional model based on the cognitive perspective.
Keywords. Affective computing, appraisal theory of emotion, virtual characters, facial animation.

1 Introduction

Emotions affect in many aspects of our live and many researchers have been studying trying to understand the fundamental aspects of them. They affect in the evaluative judgement, in the memory, in the creative thinking and in the decision making process, where some authors as Picard [1] estimated the computers would improve their decisions if they had emotions or emotional mechanisms which work with the computer rule systems. The emotions also affect in the communication and social interactions. This was studied by Mehrabian [2], who shows in his research, the 93% of our message goes through non-verbal language (55%), mainly based on facial and corporal motions, and the use of the voice (38%).

If the emotion affects in the memory, creative thinking or communication, this aspect cannot be exclude in the learning process. According to Hernandez et. al [3] the affective state has been recognized as an important component in learning.

In this work we propose to include emotional interaction in the learning process by means of using ELEIN (E-learning with 3D interactive emotional agents), a 3D virtual tutor which is capable of interacting with the student having into account the emotional state of the student. The aim of the ELEIN system is to achieve emotional multimodal interaction and communication in e-Learning environments, which allows educational contents to be expressed in a new communication language on the website. The main interaction element between the student and the environment consists in a Three Dimensional Educational Agent, with voice synthesis capacity in real time, fully integrated in the contents of the courses.

The paper is organized as follows. In section 2, we explain the importance of researching in both, the emotions in the learning process and the presence of the virtual tutor. Regarding to the emotions (section 3), we differentiate between the generation of the emotions when the virtual tutor is explaining the contents of the e-Learning course (section 3.1), and the generation of the emotions when the virtual tutor is assessing the student knowledge (section 3.2). We deal with the presence, by means of using an animated virtual tutor which is explained in section 4. The personification of the emotional educational agent implies to define how emotions should be expressed (section 4.1) and which are the animation techniques in order to execute the facial animation (section 4.2). At the end of this paper we explain the conclusion and future work produced by this work.

2 Using a 3D emotional agent in the learning process

The ELEIN system reached two important issues for e-Learning: the presence of the virtual tutor and the importance of the emotions in the learning process. In this work, we deal with the presence by means of the personification of the educational agent. We use an expressive 3D Avatar with voice synthesis capacity in real time, fully integrated in the contents of the courses. Integrating avatars in interactive applications has been a highly researched field in recent years. Several authors have performed evaluation involving real users to define the main advantages of interaction through avatars. Due to the following researches, we use a User Conversational Interface, in the form of a Three Dimensional Educational Agent, as main interaction element between the student and the environment:

- **It facilitates social interaction with the machine.** In 1994, Nass et al. [4] performed five experiments that revealed that the individual interactions of computer users are fundamentally social. Recently, Prendinger et al. in [5] also included that the user hopes to obtain the same type of social behaviour. Therefore, they proposed to give the interface with personality aspects and voice synthesis to improve the human machine interaction.
- **The student then considers the system to be more reliable and credible.** A user needs to believe in an agent's reliability in order to have the confidence to delegate certain tasks to it. There are evaluations that demonstrate that confidence and credibility increase with the personification of the agent, in other words, by giving it a face, eyes, body or voice. If the aspect of the character is also realistic, the agent is seen to be more intelligent and friendly [6].
- **The commitment of the student increases.** Personifying the agents increases the user's commitment to the application. In learning environments, for example, personifying the virtual tutor has a positive impact on the perception of the students, particularly, if there are also emotional responses [7].

– **It catches the attention of the student.** Hongpaisanwiwat et al. [8] concluded that the avatar is capable of catching the user's attention and that this increases if the avatar is credible, as it generates the illusion of life in the system.
– **It focuses the student's attention.** An avatar can be used to focus the user's attention to points of interest, which is of great importance for learning environments [5].

Animated pedagogical agents have particular competence. As a real teacher they can show how to manipulate objects, they can demonstrate tasks and they can employ gesture to focus attention [9]. Following these researches, we decided to use an animated 3D avatar as virtual tutor.

However, there is another important issue: the importance of the emotions in learning. Learning process implies cognitive aspects as well as socio-emotional aspects: in real world, teaching also implies to observe the students affective behavior in order to detect affective responses which can express interest, excitation, confusion, etc. and suggest a review of the actual interaction flow [10]. The use of these animated pedagogical agents with emotional capabilities in an interactive learning environment has been found to have a positive impact on learners [11].

3 Generation of emotions in the learning process

The main advantage of using virtual tutors within interfaces is to allow the student to interact intuitively with the system by giving him the illusion of communicating with a real tutor. This illusion is obtained by mimicking human communication, i.e. giving the avatar the ability of expressing emotions through facial and body gestures.

However, the way of giving the avatar the ability of expressing emotions can be different depend on the learning process phase. In the learning process, there are, at least, two differentiated phases: the phase in which the tutor is explaining the course content and the phase in which the student is assessed by the tutor. In a computational system, the generation of the emotions is different in both phase.

– **Explanation Phase** (Fig.1 a.). In this phase, the explanation of the virtual tutor had been pre-defined by the application designer (the real tutor) so the virtual tutor receives and executes pre-recorded emotions.
– **Assess Phase** (Fig. 1 b.). Dynamic generation of emotions: In this case, there is no pre-recorded emotion, but rather all the emotional responses are generated as the result of a process to evaluate the interaction events produced in the system.

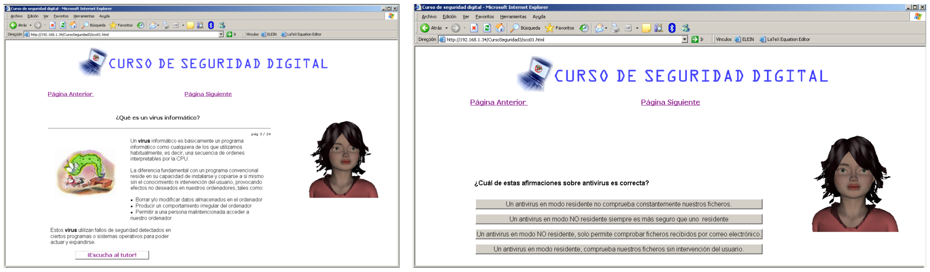

Fig. 1. Screenshot from e-Learning course of ELEIN system. a) Explanation Phase. b) Assess phase.

3.1 Explanation phase: Static generation of emotions

During the explanation phase (Fig.1 a.) the student goes across web pages which have the course content. This content is shown with text and images, in HTML format, as traditional e-Learning courses. However, the content is also explained by an emotional 3D virtual tutor. The virtual tutor enhance the main concepts of the course. This explanations should be previously defined by the content designer (the real tutor who is creating the e-Learning course). The facial expressions and emotions are also pre-defined by the content designer, that means, they are generated statically.

Static emotional interaction is generated as a pre-defined reaction in the system. The fact of having to predefine the emotional behaviour implies that the system has tools to define this behaviour. This need has been researched by other authors who concluded that one of the most efficient ways of providing the system with static emotional qualities is by labelling, in other words, labels that will define the facial gestures, emotions or intensities (in the case of the avatar) that will have to be reproduced at a specific moment, in addition to the text that the system has to reproduce. The need to label the behaviour led to an analysis of the main existing languages that was published in [12]. We based our comparative study on the main features required by our animation engine (explained in section 4): facial animation, corporal animation, text-to-speech production and emotional representation. As can be seen in the analysis published in [12], the most comprehensive markup languages were VHML [13] and RRL [14], as they include all the parameters relating to emotion, body and facial animation, and the dialogue labelling. Finally, in this work, VHML has been chosen as it is a standard that allows all aspects of static emotional interaction to be defined.

In order to make easer the process of pre-defining the emotional behavior of the avatar while it is explaining the course contents, we have developed a highly innovative tool based on VHML that allows any non-specialized user (in this case, the real tutor) to define and automatically execute a complete avatar animation with high level of expressiveness.

3.2 Evaluation phase: Dynamic generation of emotions

In the evaluation phase (Fig. 1 b.), the emotions can not be pre-defined, since the emotions has to appear dynamically depending on the user feedback and emotional state. In this case, the emotions will be the result of a cognitive process that evaluates the student events. There are principally four different perspectives on emotion: the Darwinian, the Jamesian, the social constructivist, and the cognitive. For the implementation of emotional computers, the most followed perspective is the fourth one. In this case, emotions are considered as responses to the meaning of events with regard to the individual's goals and motivations. There are a lot of emotional models which follows this perspective. We tried to find which one is the emotional model that better fits with an interface depending on the application requirements.

In general, the *appraisal theories* indicate that the result of an emotional reply comes from a dynamic assessment process of the needs, beliefs, objectives, worries or environmental demands. Each emotional model use different appraisals. Therefore, for choosing an emotional model that fits with the application in which it is going to be integrated, it is very important to know what kind of information about the user and system we have; which are the application requirements, how the user will interact and communicate with the system and what will be the avatar role. For this work we have the following requirements about the system: The avatar is an emotional interaction element in the interface and we do not have any previous information about the user, just the ones that are generating during the interaction and are implicit in the application (such as pass an exam). At this point we tried to find the emotional model that better fits for a system with this characteristics.

There are several emotional models on which this cognitive perspective have been based, such as those developed by Aaron Sloman [15], Lazarus [16], Ortony, Clore y Colins [17] or Roseman [18]. Within this set, the Ortony, Clore and Colins (OCC) and the Roseman models were explicitly designed to be integrated in computers and offer a rule-based mechanism to generate cognitive emotions. In fact, many authors have developed computational systems based on emotional models. For example, the Roseman model was implemented by Velasquez in Cathexis [19]. The OCC model has been extensively implemented. Special mention should be made of the models developed by Elliot [20] and by Bates [21]. As limitations were found in both models, other authors have combined them, such as El-Nars [22] o Buy [23]. In his thesis [24], Bartneck states that the reason why the majority of projects in this area choose the OCC model is that is the only one that offers a structure of variables that influence the intensity of the emotion. In a comparison between both models, significant differences have been found that make the use of each of them mainly depends on the level of interaction that is desired to obtain in the system. For example, it was concluded that the OCC model takes into account the standard models and preferences of the user in its evaluation process, while Roseman only evaluates according to objectives and this means that some emotions relating to attitudes or standards (taste/distaste or anger) cannot be specifically defined. However, in eLearning not always the system has the student attitudes or standars, in this case the system only has the objective of the student and the information occurred during the learning process. Therefore, the Roseman implementation may be more appropriates for this case. In general, in this paper, we have opted for the Roseman model for the following reasons. On the one hand, this model considers surprise emotion within its 17 emotions and this emotion is very important as Ekman [25] considers it as one of the six universal basic emotions, and our facial animation engine is based on Ekman studies. However, the OCC model does not contemplate it. On the other hand, as Barneck concluded [24], a log function needs to be stored which will help to assess the probability, fulfilment and effort of each event to categorize the emotions, an element that is not contemplated in the OCC model.

3.3 A computational Roseman's model

We implement Roseman's model by means of a rule-based system based on the table shown in Fig.2. In this table are presented the six cognitive appraisals which determine whether an emotion arises and which one it is; 1)if the event is self-caused, other-caused or circumstance caused, 2)if the event is unexpected, 3)if the event is a motive consistent or motive inconsistent, 4) if the person can control of the situation (in case the event is motive inconsistent), 5) if the event is certain or uncertain and 6) if the event is noticed as negative because it blocks a goal or because it is negative in its nature.

<table>
<tr><td colspan="2" rowspan="3"></td><td colspan="2">Positive emotions</td><td colspan="2">Negative emotions</td><td rowspan="3"></td></tr>
<tr><td colspan="2">Motive-Consistent</td><td colspan="2">Motive-Inconsistent</td></tr>
<tr><td>Appetitive</td><td>Aversive</td><td>Appetitive</td><td>Aversive</td></tr>
<tr><td rowspan="5">Circumstance - Caused</td><td>Unknown</td><td colspan="4">Surprise</td><td></td></tr>
<tr><td>Uncertain</td><td colspan="2">Hope</td><td colspan="2">Fear</td><td rowspan="2">Weak</td></tr>
<tr><td>Certain</td><td>Joy</td><td>Relief</td><td>Sadness</td><td>Distress</td></tr>
<tr><td>Uncertain</td><td colspan="2">Hope</td><td rowspan="2">Frustration</td><td rowspan="2">Disgust</td><td rowspan="2">Strong</td></tr>
<tr><td>Certain</td><td>Joy</td><td>Relief</td></tr>
<tr><td rowspan="4">Other – Caused</td><td>Uncertain</td><td colspan="2" rowspan="4">Liking</td><td colspan="2" rowspan="2">Dislike</td><td rowspan="2">Weak</td></tr>
<tr><td>Certain</td></tr>
<tr><td>Uncertain</td><td rowspan="2">Anger</td><td rowspan="2">Contempt</td><td rowspan="2">Strong</td></tr>
<tr><td>Certain</td></tr>
<tr><td rowspan="4">Self – Caused</td><td>Uncertain</td><td colspan="2" rowspan="4">Pride</td><td colspan="2" rowspan="2">Regret</td><td rowspan="2">Weak</td></tr>
<tr><td>Certain</td></tr>
<tr><td>Uncertain</td><td rowspan="2">Guilt</td><td rowspan="2">Shame</td><td rowspan="2">Strong</td></tr>
<tr><td>Certain</td></tr>
</table>

Fig. 2. Roseman's model [18]

The implemented model has been integrated in a prototype with the required requirements in order to prove it in a real application. This application consists in an e-Learning course in which the avatar gives to the user emotional feedback related with its results. The interface of the course (Fig. 1 b.) is composed by an emotional avatar, which expresses the emotions given the Roseman's model and by a questions zone, which are taken from a XML file. When the test exam begins the emotional module starts to assess the event following the Roseman's appraisals described above.

The first appraisal is the agency, this means whereas the event is self-caused, other-caused or circumstance caused. An event is circumstance-caused whether the user has been started and the system gets the first user reply. Then, the first thing to do is to ascertain if the answer is correct.

If it is correct, the system checks the **second appraisal** of Roseman's model; whether this is unexpected or not. For achieving this information we use the relative frequency ($f_s = n_s \div n$) which is a number that describes the proportion of successes happening in a given test exam. If the system gets an unexpected reply, the avatar will show the *SURPRISE* emotion.

If this is an expected response, the **third appraisal** to treat is whether it is motive-consistent or not. An event is motive-consistent whereas it helps to achieve one of the subject's goals and it is motive-inconsistent if it threatens it. Anyway, the main goal here is pass the exam. As we are evaluating a correct answer, the user will be in a motive-consistent. Inside the set of emotions generated by motive-consistent event we get *JOY* if the event is motivated by the desire to obtain a reward (the player is wining) or *RELIEF* if the desire to avoid punishment. If the answer is not correct, the event is motive-inconsistent. It follows the same sequence rules than above. If it is unexpected, then we get *SURPRISE*. If not, the system checks whether it is appetitive or not.

In the case of a failed reply the emotion is also affected by the **forth appraisal**, the user potential to control the situation. For guessing it (if he/she can still win) we use the Eq. 1. For achieving this equation we start with the binomial distribution function ($P(X = k) = \binom{N}{k} P_{ok}^k (1 - P_{ok})^{N-k}$) which gives us the discrete probability distribution of obtaining exactly k successes out of N trials, taking into account that the probability of getting right one question is P_{ok}. Knowing that the user goal is to answer k correct questions for passing the exam and he/she answered n questions, we need to calculate the winning probability at each point of the test exam, depending on the x previous correct answers. We follow the Eq. 1. If the user can control the situation and the event is appetitive, then we get the *FRUSTRATION* emotion. If he/she can not control the situation, the avatar will show the *SADNESS* emotion. In the case that the event is aversive we get the *DISTRESS* emotion if he/she has not potential control and again *FRUSTRATION* if he/she has it.

$$\sum_{i=k-x}^{N-n} \binom{N-n}{i} P_{ok}^i (1 - P_{ok})^{N-n-i} \tag{1}$$

All of this occurs when the event is certain (the student has already answered the question). Whereas the event is certain or not, is the **fifth Roseman's appraisal**. For assessing this appraisal, the system calculates the time that the student has to answer by means of an internal clock. While the user is not answering, the system gets an uncertain event. In this case, the computational emotional model looks at the success probability which is also calculated through the relative frequency. If the user has a high probability of getting right then the system gives us the *HOPE* emotion. If not, then the control potencial is achieving again through the equation 1. If the user could not control the situation, then the avatar will show the *FEAR* emotion, if not, we will get *FRUSTRATION*.

The first Roseman's appraisal that we assessed is the agency of an event. At this point we got the events caused by the circumstances but Roseman contemplates two more kinds of event-causes, the other-caused events and the self-caused. The emotions generated by the assessments of this kind of events will appear when the system know if the student pass or not. The first ones will show the avatar feeling about the user game and the other ones will be the avatar prediction about the user feeling. The rules followed for obtaining this emotions are the ones related with the appetitive and control potential appraisals. Then we will get the *LIKING*, *DISLIKE* and *ANGER* emotions for other-caused events and *PRIDE*, *GUILT* and *REGRET* for self-caused events.

The last appraisal, the kind of problem, describes whether an event is noticed as negative because it blocks a goal or because it is negative in its nature. In this kind of application we always get the first kind of problem.

4 Animated pedagogical agent

4.1 The expression of emotions

Several researches have been centred in defining how the human express the emotions he/she is experimenting. Darwin was one of the pioneers in studying it. His studies made an emotional theory which have followed researchers as Ekman [25]. The Ekman's theory is maybe the most successful and most followed for representing facial expressions. In 1978 he developed a system for coding the facial actions called FACS (The Facial Action Coding System). FACS is a comprehensive, anatomically based system for measuring all visually discernible facial movement. FACS describes all visually distinguishable facial activity on the basis of 44 unique action units (AUs), as well as several categories of head and eye positions and movements.

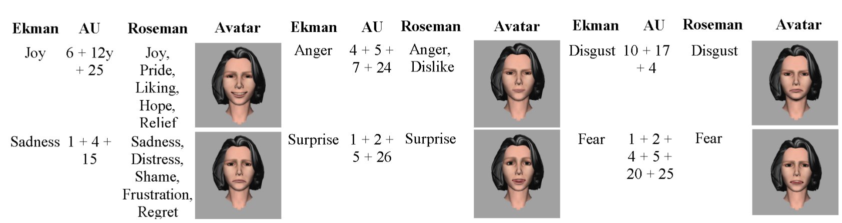

Fig. 3. Relation between Ekman's emotions, AUs and Roseman's emotions.

In our work we transfer these studies to the emotional dramatization of the avatars. The animation techniques used for performing the facial expressions are explained in chapter 4.2. For the animation models required we use the 14 AUs (Fig.3) which describe the facial activity in each emotion.

The first problem we found for using the Ekman work is that he defined only six basic emotions and we get 17 from the Roseman model. The main reason of using this six basic emotions is that Ekman and his colleagues gathered evidence of the universality of this six facial expressions of emotion and they can be combined to obtain other expressions. One of our goals [26] is that the avatar must be multilingual so it should not express emotions dependents on the culture. Kshirsagar in [27] grouped OCC and Ekmans emotions within 6 expressions to represent the emotional states and to reduce the computational complexity. He also makes this categorization using the basic expressions as a layer between visible facial expressions and invisible mood. Following this research, we make the same relations with the Roseman's emotions shown in Fig.3.

4.2 Facial Animation

Facial expressions are obtained through the animation of the head, lips, eyes, pupils, eyebrows and eyelids. These animations are easily mapped for humanoids. Some animations are generated making individual deformations or translations over the object in a determined trajectory. This technique is used for the pupils or the global head pose. Some other animations, like lip motion, are achieved using the morphing techniques developed by Alexa [28]. Let us briefly summarize the morphing technique used: first, we establish an appropriate set of basic objects (B_i in Fig.4 and Eq. 2), in such a way that all face expressions necessary to produce the animation can be obtained from combinations of these basic objects. We use a set of basic objects made by the the 14 Ekman's AUs defined in Fig.3 and another one called default face which shows the neutral face of the avatar.

$$V(i) = \sum_{j=1}^{n-1} a_i B_i = (\sum_{j=1}^{n-1} a_i B_{ij}) \tag{2}$$

The animations are represented by one geometric base and a set of key frames (defined by a vector of weights). Each value of this vector corresponds to the interpolated value (a_i in the facial animation engine module shown in Fig.4 and Eq. 2). The sequences of animations are set defining the operations in eq. 2 with the required input values. The facial animation engine module in Fig.4 illustrates this process.

The architecture works as follows: First, Roseman's model receives the application goal (in this case it recibes the percentage of the successes that the student should get right in order to pass the exam). When the interaction starts, Roseman's model is receiving each user input (in this case, it recibes the reply to each question). Following the rules described in section 3.3, the output of this module is the emotion that the avatar should express. In this point, the system asks if the interaction should be verbal or non-verbal. If the interaction is non-verbal, then the emotion tag goes directly to the animation engine. For a verbal interaction we have a short database of predefined markup text for some emotions. The markup text is transferring to the pre-process module, which interprets the text and extracts the emotions, gestures and the precise moment

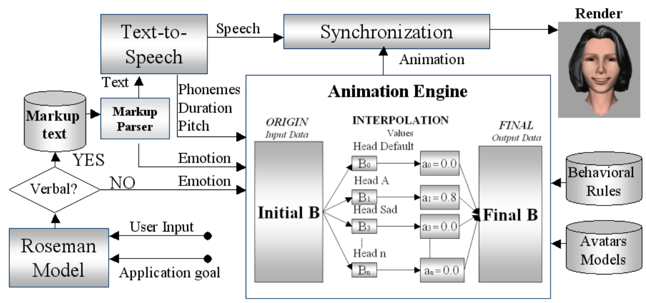

Fig. 4. System Architecture.

when they have to be reproduced. This information is transferred to the graphic platform for controlling facial expressions. The text to vocalize, the emotions and events related to them are also transferred to the Text to Phoneme module. The Text to Phoneme module calculates the chain of phonemes necessary to vocalize the message contained in the text with the indicated emotion, assigning to each phoneme its prosodic characteristics, mainly its duration and pitch. These prosodic characteristics are transferred to the graphic platform. In the graphic platform, with these prosodic data, each phoneme will be associated to its corresponding viseme (visual representation of the phoneme) by means of morphing techniques. The vocalized facial animation is based on the parameters coming from the Text to Phoneme module and a set of internal behavior rules (associated with emotions).

5 Conclusions

The aim of the ELEIN system is to achieve emotional multimodal interaction and communication in e-Learning environments. The ELEIN system reaches two important issues for e-Learning: the importance of the emotions in the learning process and the presence of the virtual tutor.

Regarding to the emotions, we differentiate between the generation of the emotions when the virtual tutor is explaining the contents of the e-Learning course (static generation of emotions), and the generation of the emotions when the virtual tutor is assessing the student knowledge (dynamic generation of emotions). In the case of Static Emotional Interaction, this is generated as a predefined reaction in the system, so it is necessary for the system to incorporate the suitable tool to define this behavior. After a deep exploration of the existing bibliography, it has been concluded that the most efficient way of providing the system with static emotional characteristics is probably the use of Virtual Human Markup Language (VHML)., i. e. with tags defining emotions, intensities or facial gestures (in the case of avatars) which should be generated by the system in a certain situation. In this research we develop an authoring tool based on VHML, which allows the real tutor to define the emotional behavior of the virtual tutor during the contents explanations without any knowledge in Computer Graphics. As during the bibliographic review no similar tool has been found, this application is considered to be an innovative contribution to the standard VHML. On the other hand, Dynamical Emotional Interaction is generated as a result of processing and evaluating every interaction event occurred in the system. In order this type of interaction to be natural and similar to human behavior and to evaluate its possible application to emotional interaction through avatars, an initial state of art of different psychological models of emotions has been made. After the analysis of the differences between the two most extended models in emotional computation, OCC and Roseman, it has been concluded that most of the authors usually base their works on OCC model. However, in this work the Roseman model has been selected to be used in the implementation of the Dynamic Emotional Interaction module, mainly because its better suitability for the eLearning course. During the implementation of the Dynamic Emotional Interaction module, the following original contributions have been made. First of all, a rule-based expert system has been defined for generating emotions. Since most of the examples of emotional systems found in the literature are based on OCC model, the design of this expert system is new and original contribution to existing bibliography.

Regarding the presence, we deal with that by means of using an animated virtual tutor. The personification of the emotional educational agent implies to define how emotions should be expressed and which are the animation techniques in order to execute the facial animation. In this work, the avatar produces an emotional expression through facial animation engine based on morphing techniques and based on the conclusions of Ekman's study about facial expression to the emotions of Roseman model and VHML, so that every emotion generated by the Static Emotional Interaction module and the Dynamic Emotional Interaction module can be expressed by the avatar according to Ekman's conclusions.

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