An Integrated Approach to Improve the Facial Emotional Behavior of Virtual Actors

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Abstract. The modeling of the autonomy of actor's behavior through emotions suggests a particular focus for the problem of constructing behavior based programs. In this particular case of animation, the target is not only to model the intelligent performance of actors, but also to achieve convincing reaction to events in general, through the actor's emotional comprehension of the context [Bates (1994)]. In providing such a kind of credibility of action in order to give people the impression of a human-like virtual actor, to model appropriate emotional expressions performance seems essential, as the face is responsible, to a large extent, for the efficiency of human communication. For that reason, this work presents as a contribution to emotion based systems, a discussion about conceptual and structural questions on modeling the autonomy of behavior for synthetic actors for application in facial animation. In this work some issues concerning the proposition of integration of the following areas are outlined: modeling of autonomous facial behavior, psychology of facial expressions, aesthetics and artistic investigation in conceiving facial emotional behavior for virtual actors. The implementation of a system based on such an approach for a more plausible automated facial emotion performance, and its main results, are outlined.

1 Introduction

The behavior autonomy is a current theme in the area of synthetic actors animation. Complex models are developed towards the animation of the autonomous attitude of the synthetic actor. In these models, the action to be executed is calculated directly, without external intervention. The calculation of the actor's action is done in relation to the particular characteristics of the environment or the initial situation, according to behavioral laws previously represented in the system.

From the point of view of actor's emotional behavior, some recent models have automatically generated different facial emotional expressions using neural networks with back propagation algorithms [Hara et al., (1992); Morishima et al., (1993)]. Some other models have attempted to develop autonomous emotional behavior of synthetic actors by simulating the actor's emotional process [Mogi et al., (1992); Reilly et al., (1992); Bates (1994)].

In spite of the large variety of *ad hoc* facial expressions the models generate [Hara et al., (1992); Morishima et al., (1993)], and although the emotional methods [Mogi et al., (1992); Reilly et al., (1992); Bates (1994)] deal with emotions as a cognitive process which allows behavioral actions, these models provide neither a formal criteria with scientific basis to determine the composition of the facial expressions, nor the possibility to deliberately control the conformation and movement of the emotional expressions in different contexts.

Modeling the emotional process of the synthetic actor in respect of a given situation of context, also means to model the actor's "self control" of his "emotional responses". One of the main objectives in modeling the emotional process of synthetic actors should be to generate facial emotional behavior that should correspond to the actor's "feelings", in order to acknowledge that he, the actor, is conscious of what is going on in the environment he is inserted in, and principally, that he can intelligently react to situations.

With the purpose of modeling facial emotional behavior, in order to animate more plausible emotional expressions for synthetic actors' autonomous facial performance, this work proposes the integration of three distinct areas concerning (a) automation of emotional facial expressions, (b) psychological information about the morphological and dynamic aspects of emotional expressions, and (c) aesthetics and artistic investigation in generating facial emotional performance.

In sections 2, 2.1 and 2.2 the importance to endow virtual actors of emotional reactions in order to acknowledge the impression of intelligence is discussed. In sections 3, 3.1, 3.2 and 3.3 an integrated approach for modeling the facial emotional behavior for virtual actors is proposed. In the sections 4, 4.1, 4.2, 4.3 and 4.4 an implemented system using the approach described in the last sections, for automation of facial emotional expressions, is outlined.

2 Emotion and Intelligent Communication

An emotional reaction to an event means a subjective comprehension of the situation. The choice of the better mechanical reaction to a situation can give the impression of autonomy, but a subjective comprehension of a situation gives the impression of intelligence and individuality. A virtual actor endowed with a range of programmed actions can behave in a foreseen way to events. However, a virtual actor endowed with emotional reactions is capable of an individualized and personalized behavior. Through emotional behavior, the personal characteristics of each actor, such as personality and tics, can be better perceived (Bates 1994).

2.1 The "Illusion of Life"

Research carried out under the Oz project of the University of Carnegie Mellon, Pittsburgh [Reilly et al., (1992); Bates (1992), (1994)] observe that the emotional reactions of an agent to the situations of the world can give more efficiently the idea of "illusion of life", than other techniques of representing norms and rules of "mechanical behavior". The argument is that emotional actions acknowledges, in fact, the existence of life. To explore the emotionality of an virtual agent in interaction with the virtual world seems, for the group of the Oz project, the key to achieve "believable agents".

According to Bates [(1994)], cartoon artists have explored exactly the potential of emotions to communicate the essence of life. Through the artistic investigation about the "essence of humanity", the cartoon artists have reached with success, even from caricatured personages, the "illusion of life".

2.2 Virtual Reality and "Believability"

Computer scientists and artists of Virtual reality have used techniques of Artificial Intelligence (AI) to model the behavior autonomy of virtual humans in order to improve the communication of virtual actors.

However, in using AI in virtual reality, an important feature should be outlined. As virtual reality is, in essence, a graphical environment, the efficiency in modeling the interactive behavior of virtual actors is judged mainly by the perception of the realism of actor's performance, which compromise the actor's believability.

In the context of this work, the application of AI concepts to the field of virtual reality should include the treatment of the double aspect of virtual behavior: (a) the representation of the autonomous behavior process, according to the specific nature of the behavior to be modeled; and (b) the graphical or visual aspect of the behavioral action that should trustworthy represent the nature of the modeled behavior.

Concerning the requirements to construct virtual characters, Bates [(1994)] proposes "believability" as an argument for a new conception of "alternative AI". This new concept for AI should privilege the treatment of the emotional process for virtual agent's behavior, in order to determine believable reactions for actors, instead of the "idealized view of intelligence" supported by traditional AI. The conceptual issues, Bates suggests to provide *believability* of virtual agents, should concern subjects related to the modeling of the agent's emotional behavior process, such as: "reactivity, goals, emotional responses and situated social competence". In this context, it could be said that the basic premise for the "alternative AI" should be to provide, in Bates words, "emotive machines".

Nevertheless, in addition to Bates' proposition, its is equally important to consider visual concerns to treat the visual knowledge such as conformation, dynamics and control of facial expressions of emotions. These visual aspects must be related to the generation and automation of facial emotional expressions.

Visual issues in modeling facial emotional behavior are also crucial to improve the believability of virtual agents, although they should not properly seem "AI issues".

3 An Integrated Approach for Modeling Facial Emotional Behavior

"Visual aspects" of emotions concern the form and movement of gestures the actor performs to express his feelings. Such aspects are strongly relevant for the communication of the individual's comprehension about the situation and/or the environment in which he is inserted.

Through gestures and expressions individuals establish first contacts of social approximation. The expressions of emotions have an intrinsic power of communication, which are often more efficient in transmitting the actors' feelings and thoughts than words. Facial expressions can reveal subtleties of feelings and demonstrate, sometimes clearly, what is going on with individuals facing pleasant or restricting situations. Facial expressions can also be controlled by conventional behavior norms or display rules [Ekman (1984)]. Controlled expressions can be differentiated from spontaneous ones in form and dynamic performance.

Modeling communicational clues of facial expressions of emotions means to lead virtual actors to behave similarly to human beings. As the power of communication of these facial clues rely, in essence, on the fact that they are visually perceived, special attention should be given to representing emotional expressions in order to explore the visual effect of the emotional messages. The representation of actor's facial performance should have its fundamentals grounded on the nature of facial emotional behavior. Psychologists of emotions have given their contribution to the interpretation and codification of facial emotional expression messages. Equally important, as virtual actors are graphically generated, aesthetics and artistic investigation can contribute to the efficiency of modeling emotional behavior.

3.1 The Contribution of Psychology of Emotional Expression

Several studies in the psychology of emotions and facial expressions constitute important sources of knowledge to the construction of an emotional behavior model for animating synthetic faces. However, it is important to remark that the nature of the results of research on psychology of facial expressions is in essence hypothetical and generic, which often needs to be complemented with futher specialized investigation for specific cases.

The final report of the *Workshop on Facial Expression Understanding '92* to the National Science Foundation of USA reveals the interest of researchers in the areas of psychology, cognitive science, robotics, interactive systems and facial animation to establish a common data base on emotional expression features with the objective of facilitating and integrating the efforts of investigation [Cacioppo et al., (1993), pp. 13].

Researchers of facial animation admit the importance of a data base on facial expressions of emotions for the orientation of new guidelines of research, mainly those related to the facial image processing for application in teleconference. The basic points they claim to compose this facial expression data base concern the determination of: (a) the differentiation aspects between spontaneous and deliberate expressions; (b) prototypical examples of basic emotion expressions; (c) specifications of the nature of the events which commonly give rise to spontaneous emotional expressions; (d) the numerous emotional states which are variants of the prototypical images of basic expressions ; (e) information about the dynamics of facial expressions; and finally (f) information about the facial control clues emitted by deliberate expressions [Parke et al., (1993)].

All these aspects of the emotion expressiveness, if represented in a model, can automatically generate a wide number of different expressions of emotions with an important concentration of subtle emotional clues.

The present work proposes, hence, the treatment of the major part of the emotional expression aspects related above, referring to the conformation and dynamics of facial expressions of emotions in order to achieve more plausible emotional expressions. The treatment of this information allowed the implementation of the Expression Module for the generation of emotional expressive behavior of synthetic actors.

Although there are still some aspects of emotional expressions to be scientifically verified, intuitive conclusions about these expressive aspects can informally fill this gap of knowledge in the model, without compromising the validity of the final results.

3.2 The Contribution of Aesthetic and Artistic Investigation

In computer graphics animation, research of natural effects for synthetic images are essentially motivated by the realism that algorithms based on specific methods of physics can provide. These techniques are getting more and more sophisticated, in order to arrive at new qualities of the visual product. However, the realism of synthetic images should not be evaluated only from the technological and scientific points of view. As in any kind of visual communication, in a first instance, the aesthetics and artistic investigation in the generation of computer graphic images have the important role of attracting public attention and transmitting messages.

Similarly, in modeling emotional behavior for synthetic faces, the facial performance realism is, in fact, a composition of software techniques, scientific researches, aesthetics and artistic investigation of the nature of the emotion message.

Modeling virtual humans' behavior, does not only mean to represent scientific aspects of the constitution and behavior of human beings, but essentially to represent visual elements that can provide the refered "essence of life" to the synthetic actors.

Aesthetics and artistic investigations are efficient resorts to search for these intuitive aspects of life in a more detailed way. Aesthetics concerns the perceptive visual presentation features of things, and artistic investigation refers to the expression and communication of the artist's message according to his intuitive perception of the real world [Read (1978)].

In modeling facial emotional behavior, aesthetics can contribute to represent and decodify emotional expressions, by identifying the degree of correspondence between the emotional message and the virtual expressions. Aesthetics functions, in this case, as a refinement tool of the authenticity of graphic results in compliance with the emotion expression data.

Aesthetics can also contribute to the modeling of emotional expression behavior, by controlling the quality of communication of expressions. Aesthetics interferes directly in the implementation of the functions responsible for the representation and generation of the virtual expression data. In this way, aesthetics can help to improve the efficiency of graphic tools according to the correspondence between the resulting virtual and natural emotional expressions.

Modeling emotional behavior implies essentially processing emotional data concerning the facial expressions of different emotional situations. Artistic investigation on the nature of emotional behavior can contribute to creative resolutions for the representation of psychological information about the conformation and dynamic of emotional expressions.

3.3 Modeling Autonomous Facial Emotional Behavior

The treatment of emotional expressions features, such as the automatic codification of different types of facial expressions of emotions in muscle actions and the determination of their display time, allows the modeling of visual differentiation of facial behavior in the different situations of emotion control. These subtle facial differences are responsible for a more natural performance of the emotional facial behavior.

In modeling facial emotional behavior using psychological investigation, the idea is to take advantage of the hints provided by psychologists and to intuitively adopt decisions in order to suppress implementation impasses caused by the lack of information.

In the specific area of modeling emotional behavior, the intuitive interpretation of psychological information can allow creativity to solve some implementing constraints, with the objective of producing believable emotional expression performance.

4 An Experiment on Emotion Expression Automation

In order to automate the emotion expression generation for actor's facial emotional behavior, a system called *"Expression Module"* based on the representation of the morphological and dynamic properties of emotion expression performance was constructed [Daldegan (1995)]. This module will be further used in an *"Emotional Dialog System"* for modeling non verbal communication between synthetic actors.

During the non verbal communication dialog, the function of the Expression Module is to create, as a final product of the system, an appropriate high level script for the actor's facial emotional behavior to be interpreted by a facial animation system [Kalra et al., (1991); Kalra (1993)] for the generation of the final emotional sequences. The special rules that calculate the facial expressive movements for the script are based on facial anatomic indications of expressions of emotions.

The Expression Module provides tools for controlling the conformation and dynamics of facial behavioral movement in order to automate the creation of emotional expressions scripts. The module processes information for the animation of several emotional expressions possibilities, such as: (a) a large set of facial expressions of six categories of emotions; (b) facial expressions of blended emotions; (c) morphologic and dynamic information of spontaneous emotional expressions, as well as of deliberate expressions of simulated, neutralized and masked emotions.

The organization of the Emotion Knowledge is done in four main structures describing: (a) the emotions in terms of facial expressions, strength, and related emotion category; (b) the basic information concerning morphologic properties of the emotion expressions; (c) the basic information concerning dynamic properties of the emotion expressions; and finally (d) the facial expressions rules represent the main structure of the system, it is responsible for generating the emotion expression's scripts by dynamically interpreting the input commands, and executing the specific search in the data base structures according to facial expressions' conformation and time evolution rules.

The modeling of the natural aspects of emotional expressiveness was devised in two parts: one concerning the morphological aspects of emotional expressions and the other, the dynamic aspects.

4.1 Emotional Expression Morphologic Rules

The morphology of facial expressions of emotions is treated by rules that are responsible for the conformation of facial expressions. These rules generate emotion expression morphologic scripts for the synthetic actor's facial conformation.

Such morphological rules generate information on single or blended emotional expressions. The single expressions are represented in the emotion expression data base by categories of emotions [Ekman et al., (1975); Gosselin (1989); Wallbott et al., (1993)]. Special procedures for emotion expression blending define the conformation of blended expressions. Each facial expression data is defined in terms of *Action Units* and levels of intensity for each AU. An Action Unit (AU) represents an indivisible facial muscle action. The AUs combined together and in different ways can produce all the facial expressions, including either speech phonemes and facial expressions of emotion [Ekman et al., (1978)].

The morphological data of single and blended expressions can be modified by special rules according to the specification for the emotion expression controls, such as (a) *neutralization*, when the face tries to reduce de strength of the muscular movements of a felt emotion [Ekman et al., (1975)]; (b) *simulation*, when the face tries to show an expression of a non felt emotion, normaly the simulated expression shows asymmetry in the left side [Sackeim (1978)]; or (c) *masking*, when the face shows an expression of a non felt emotion to cover a felt emotion [Ekman et al., (1975)].

The blending and control rules respect the importance each AU has in to typically characterize [Ekman et al., 1975] and in to identify [Bassili (1979)] an emotion in its corresponding expression. The AUs typically displayed by expressions of a same category are classified in the system as *typical AUs*. The AUs that most identify an emotion on a expression are classified in the Expression Module as *identifier AUs*. The *identifier AUs* are a special class of *typical AUs*. The morphological rules use these two concepts of *typical* and *identifier* AU to compose controlled and blended expressions. The conformation of controlled expressions is calculated according to the specifications of each one of the three types of emotion control. In the same way, the composition of blended expressions is done according to the strength of the basic emotions aroused by the emotional experience.

4.2 Emotional Expression Dynamic Rules

The rules of emotion expression dynamic concern the display aspects of facial expressions of emotions. These rules establish dynamic control procedures for the display of facial expression of emotions, such as: (a) the dynamic display data for spontaneous emotions, that indicates regular periods for each dynamic phases of onset, apex an offset; (b) the dynamic display data for deliberate emotions, that indicates irregular periods of dynamic phases, according to the dynamic peculiarities of each type of emotion control [Ekman (1984); Ekman et al., (1980), (1982); Hess et al., (1990)]. These dynamic control rules generate emotion expression dynamic scripts for the synthetic actor's facial performance.

4.3 Creative Resolutions to Implement Constraints

The data collected from different researches in the area of psychology of facial expressions presents an inherent arranged structure that could be easily adapted and represented in the Expression Module [Daldegan (1995)].

Nevertheless, in spite of the structural aspect of the psychological data, some information for the refinement of the conformation of blended and controlled expressions are not provided by psychologists and theorists of emotions in such detail.

The rules about the generation of conformation data of blended and controlled expressions were implemented in the Expression Module on the basis of the intuitive interpretation of some psychological research about the relation between the AUs composition and the categories of emotions [Ekman et al., (1975); Bassili (1979)].

In this way, concepts such as *typical* and *identifier AUs* are introduced in the Expression Module in order to create new single expressions of emotions under the simulation and neutralization controls, as well as spontaneous blending and masked expressions. The visual results present the rich subtle forms of micro and macro expressions, defined by Ekman et al. [(1975)] as being facial clues that reveal signs of spontaneous and deliberate emotions, respectively.

More details about the construction of the Expression Module are further described in Daldegan et al. [(1995)].

4.4 Results

The Expression Module provides an atlas of several and varied synthetic facial expressions of emotions. Expressions with subtle variations can be generated by employing the control and blending rules on the single emotion expressions represented at the emotion expression data base.

Although the recognition of computer generated facial expressions is strongly influenced by the degree of efficiency of the facial and animation models, the evaluation of the single emotional expressions provided by the Expression Module presented satisfactory results of recognition.

According to preliminary judgment studies, synthetic facial expressions can be relatively easily recognized, only expressions of the fear category presented low percentage of agreement. These results agree with some statistics about the recognition of human emotional expressions observed by Ekman et al. [(1975)]. The great percentage of the non recognized single expressions did not present, or presented in very low intensities, the *identifier AUs*, the AUs of specific facial regions which provide the easiest identification of emotion expression, as Bassili [(1979)] had observed. Concerning blended expressions, it was informally observed that, in spite of the difficulty for the volunteers to identify the emotion components of blended expressions, some emotions represented by its *identifier AUs*, in the expressive composition, could be better perceived.

These results are useful to evaluate the satisfactory validity of the integrated approach, about elements of automation, psychology of facial expressions and aesthetics, considered to implement the Expression Module. They reveal the plausibility of the emotion expression's morphologic and dynamic rules.

More extensive judgment studies will be further carried out in order to evaluate the morphologic and dynamic aspects of blended and controlled expressions.

5 Conclusion

This work proposed the discussion about the integration of elements of computer science, psychology of facial expressions, art and aesthetics focusing the attention on the control of facial emotional expression features that neither was largely explored in traditional facial animation, nor in emotion based facial systems, in order to allow the generation of a varied and rich emotional expression performance. This integration provides a technical, scientific and intuitive basis for the automation of facial emotional behavior. Such an approach seems efficient to the conception of "virtual human life". It concerns the computer support for the construction of the virtual environment and actors. This approach also provides an appropriate knowledge basis for the modeling of the actor's autonomy and individuality in his environment based on human emotional facial performance. Finally, such an approach supports the improvement of the visual aspects of virtual actors' emotional expressiveness that are the basic nature of computer graphic generated human representation.

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