Emotional Expression in Virtual Agents through Body Language

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Abstract. Virtual agents are used to interact with humans in a myriad of applications. However, the agents often lack the believability necessary to maximize their effectiveness. These agents, or characters, lack personality and emotions, and therefore the capacity to emotionally connect and interact with the human. This deficiency prevents the viewer from identifying with the characters on a personal level. This research explores the possibility of automating the expression of a character's mental state through its body language. Using a system that animates a character procedurally, we provide tools to modify the character's body movements in real-time, so that they reflect the character's mood, personality, interest, bodily pain, and emotions, all of which make up the current mental state of the character.

1 Introduction

Virtual agents must be able to interact and communicate effectively with a human. The major difficulty in this task is the fact that believability of the virtual character is essential for effective interaction. Believability is the ability of the agent to be viewed as a living, although fictional, character. We believe that only if the user views the agent as a living character will the user seriously mentally engage him/herself with the agent. Through this mental engagement, the virtual agents will be able to be maximally effective in their interaction with humans and will be able to connect with the human on a personal and emotional level. This connection is especially important for applications that attempt to significantly affect the user. These applications may include certain educational applications or games that aim to challenge the individual emotionally.

We believe that individuals will be able to better relate to virtual agents if these agents exhibit personality and emotions. Their believability would increase, since the expression of personality and emotions causes the agents to seem more like living characters. The objective of this research is to translate the high-level qualitative concepts of personality and emotion into low-level communicative physical gestures. In other words, we have enabled the character to perform body language based on his/her current mental state, which may include personality, emotions, mood, interest, or even bodily pain.

2 Background

Researchers have performed a considerable amount of research related to interactive virtual humans. One prominent area is that of Embodied Conversational Agents, which are agents that converse with humans. Justine Cassell, a pioneer of this area, has performed extensive research on the complex interaction between verbal cues (e.g., speech) and non-verbal cues (e.g., expressions, nods, gestures) [2]. Although our project does not deal with conversation, their research of communicative body language is very relevant to our work.

Laban Movement Analysis is a system for observing and notating all forms of movement. Researchers at the University of Pennsylvania have been using this system to mathematically gather essential gesture components from motion-capture and video data. These gesture components, which represent various characteristics, can then be applied to other motions [1]. Similar to our work, they are focusing on the implementation of movements that make up body language however our approaches are quite different.

The main goal of this research is to provide the capability to express a character's mental state through his/her body language in order to invoke an emotional response in the user. The character's expression will come in the form of facial expressions as well as body language. This system is meant to be a tool for the developer of any system with virtual agents. As the developer specifies the character's different personality or emotional characteristics, the character will modify its body structure, current movement, and/or create additional movements to reflect these characteristics.

The system presents the developer with control over seven main mental state characteristics that the character can express. These characteristics are confidence, anxiety, interest, thought, anger, defensiveness, and pain. The developer can control the quantities of the characteristics present in the character. These characteristics produce some body language, or automated change in the character's behavior, that is expressive of this mental state. We chose these seven characteristics because we felt that they were common characteristics that allowed for effective displays of body language. There is nothing inherently special about these seven characteristics, nor do they form a comprehensive set. Rather, these are the examples that we chose to demonstrate the power and effectiveness of using body language. The system can be extended to include any characteristic for which body language can be defined.

We use procedural animation to animate the character because of the real-time flexibility that the movements require. All body movements of the character are created algorithmically in real-time. For this project, we have used the PEAL character animation system and Playspace's emotion model (both described below).

2.1 Perlin Emotive Actor Library

Our system is built on the Perlin Emotive Actor Library (PEAL), which is a procedural, 3-dimensional, character animation system written in C++ using OpenGL [4]. We use a masculine character provided by the PEAL system, which supports the procedural animation of the body and facial features as well the character's walking action. We have built our system as a layer on top of the existing PEAL system.

Ken Perlin has won an Academy Award for his creation of Perlin Noise, which is noise created by a rhythmic stochastic noise function. Perlin Noise can be added to the joint angles of the body parts of the character in the PEAL system. This noise causes small irregular rhythmic movements, which give the impression of some natural fidgeting, the intensity of which can be adjusted.

2.2 Emotivation Model

Playspace, Inc., a game company in California, has performed extensive research on a model of emotion that can control facial expressions. This research includes analyzing, representing, and modeling facial expressions as well. They have developed a theory for understanding the expression of human emotion through facial expressions. They have broken down emotions into three primitive scales, called emotivations, each of which is a spectrum with two opposing notions at the ends. These three continuous dimensions are excite-depress, pain-pleasure, and aversion-desire. Each of these primitive scales directly maps onto a continuous range of facial movements between two extremes (see Figure 1). The facial expression of any emotion can be made up of some combination of values of these three spectrums.

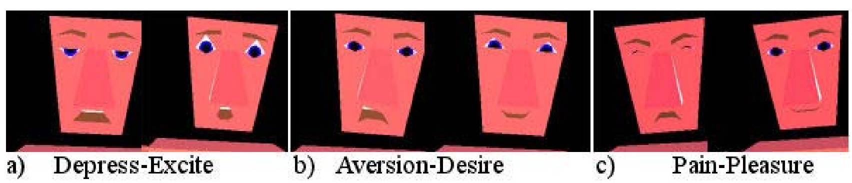

Figure. 1. These facial expressions correspond to the extremes of the stated emotivations

The level on the depress-excite continuum directly relates to the amount of energy that is exhibited by the character. The aversion-desire continuum deals with the amount that the character is attracted to or repulsed by an object. The pain-pleasure continuum describes the amount of pain or pleasure that the character is experiencing. We have used this model for the facial expression component of this project.

2.3 Uses and Applications

As mentioned above, this system is meant to be a tool for the developer of applications with interactive agents. The various mental state characteristics and their parameters will be accessible to the programmer through an API.

Although any application with interactive agents will benefit from the addition of some personality or emotion-based body language, our system is particularly useful for agents in virtual worlds. Virtual reality and games would benefit hugely, since the agent interacts with the world and experiences different situations that may cause changes in his mental state.

3 Actions and Body Movements

In our system, when certain mental state conditions are met, the character may perform an action that is representative of this mental state. While an action is being performed, if the conditions change such that the action's conditions are no longer met, then the character terminates the action as soon as possible. All of the character's actions and movements at any given time make up his body language.

In our work, we have created body language by specifying the movements of various body parts as functions of the mental state characteristics over time. The PEAL system implements these movements in the geometry of the 3-dimensional character and handles the movements' repercussions to the rest of the body through the use of forward and inverse kinematics, which are crucial to procedural character animation.

All actions that make up body language are assigned a priority level depending on the importance of the action. Any actions created by the programmer should be assigned a priority level as well. In the case of a conflict between actions (e.g., two actions use the hands), this priority level will determine which action is performed.

The duration and delay time of actions are often determined probabilistically within a certain range. For an action that is representative of a certain mental state characteristic, often the average duration of the action is directly proportional to the level of the characteristic and the average delay of the action is inversely proportional to the level of the characteristic. The higher the characteristic level of the character, the sooner and for a greater amount of time he will perform the action. This timing helps to communicate the intensity of the characteristic to the user and the probabilistic nature helps to maintain unpredictability.

4 Mental State Characteristics

Emotions, personality traits, moods, and mental dispositions all contribute to a person's mental state. We have chosen to focus on seven main characteristics for this project: confidence, anxiety, interest, thought, anger, defensiveness, and pain. We have implemented a representative set of body language for each characteristic, which the programmer can set to any value on a continuous scale.

If multiple characteristics affect the same body movements, then some of these movements (e.g., posture) can be averaged together by means of a weighted average, the weights of which are the levels of the characteristics causing the effects.

See Figure 2 for a few screenshots of different body language performed by the character in our system.

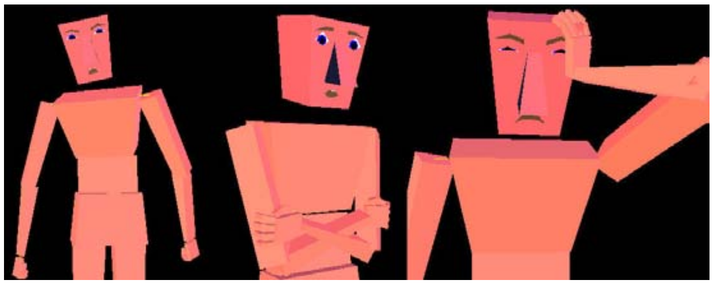

Figure 2. The character in our system expressing (left to right) anger, defensiveness, and headache

Confidence

The confidence scale is from total lack of confidence to complete confidence. The facial expression of the character is controlled by the depress and pleasure emotivations. As he becomes unconfident, the depress emotivation is added and the character gains a subdued expression. As he becomes increasingly confident, a slight amount of pleasure is added and the character forms a confident smile.

The posture of the character is directly proportional to the level of confidence. A complete lack of confidence will lead to a self-doubting hunched-over character. As confidence increases, the character's posture straightens with his chest out and chin up. The speed of the character's gait, which is affected by stride duration, stride size, and horizontal leg lift, is directly proportional to confidence.

As the character becomes increasingly confident, he occasionally places his hands behind his back with his chest protruding outward. If extremely confident, the character may clasp his hands behind his head in a relaxed resting position.

Anxiety

The anxiety scale goes from calmness to total anxiety. As the character's anxiety increases, he becomes slightly worried and gains a facial expression of excitement. The value of the depress-excite emotivation increases linearly with the anxiety level.

As anxiety increases, the level of Perlin noise increases linearly between a certain range. This increase creates the effect of the character becoming increasingly nervous and fidgety as his anxiety level goes up. The anxiety level of the character is also reflected in the stress carried in the character's shoulders. As anxiety increases, the character's shoulders gradually become increasingly tensed up, or shrugged.

If the anxiety level is greater than a certain value, the character may widen his lips and begin biting his nails.

Interest

If the agent is in a virtual environment or is a character in a game, then he may have a certain mental disposition towards various encountered objects (or characters). The interest scale is from dislike of the object to affinity for the object. The midpoint corresponds to being completely indifferent to the object. The emotivation of aversion-desire is directly proportional to the level of interest.

If the character has no feelings towards any object for an extended period of time and if the character has a certain amount of the depress emotivation (lacks energy), he gets bored and may yawn. However, if the character is interested in or is averse to an object, then it holds the character's attention and therefore his gaze. As these feelings of interest and aversion intensify to a certain amount, the character rotates towards and away from the object, respectively. As the feelings become even stronger, the character begins to walk towards or away from the object.

Thought

We must first define *thought* precisely. With the use of the five senses, an individual is taking in a constant stream of information through the process of perception. To think, however, is to go beyond this automatic perceptual reflex and to actually formulate a mental event. In order for a character to uphold the illusion of being a living non-robotic creature, it is necessary for the character to take part in, or pretend to take part in, natural actions such as thinking. In order to be effective, a character must allow the viewer to be able to see his thought process, which can be accomplished through the eye-accessing cues defined in neuro-linguistic programming (NLP) [3].

Neuro-linguistic programming (NLP) is essentially a model of communication and personality. It deals with the studying and modeling of human behavior. One relevant aspect of NLP is eye-accessing cues. According to NLP, when humans think, they commonly make short eye movements in observable directions. These movements can indicate to which of the five senses the thought relates and whether the thought is a memory or an imagination. Space does not permit us to go into greater detail here.

The thought scale is from lack of thought to deep thought. As the character becomes more deeply lost in thought, his natural fidgeting, or the Perlin noise in his joints, decreases. When maximally deep in thought, he is almost completely frozen.

Anger

The emotivations of excite, desire, and pain allow the character to facially express his anger. The feeling of anger can certainly cause one to become agitated or excited. An angered character has the desire to mentally involve and concern himself with a certain situation. Anger is a painful experience and, especially if present over a long period of time, can be unhealthy and harmful.

The natural fidgeting of the character, determined by the amount of Perlin Noise in the joints, is directly proportional to the level of anger. As the anger level rises, the character's body starts trembling and eventually seems to boil over with rage.

As the character's anger increases, he gradually begins to gaze towards the entity at which he is directing his anger and, at maximum anger, holds a steadfast gaze on this entity. If the anger level of the character rises above a certain point, the character performs the hostile gesture of clenching his fists tightly. If he is walking, he will swing his clenched fists as he walks.

Defensiveness

When protecting oneself from an outside force, whether the force is a serious threat or a mild social threat, it is common for individuals to put a barrier between themselves and the outside force. An individual may consciously or subconsciously defend him/herself by covering up or blocking part of his/her body.

The level of defensiveness is linearly related to the excite emotivation, which shows the amount of energy (physical and mental) that the character is expending in protecting himself. When experiencing defensiveness, the character will have a small amount of desire. He possesses the desire to protect himself from some entity.

When defensive, the character will periodically gaze away from the entity of which he is defensive. This action of gazing away prevents confrontation and prevents the character from giving any impression of aggressiveness. However, if the level of defensiveness is greater than a certain amount, then the character is facing an imminent threat and will not gaze away, since the avoidance of confrontation is no longer a possibility. He must physically protect himself by engaging in an action of self-defense. This action must be specific to the current threat, so we have implemented a generic action in which the character places both hands in fists in the air in front of him to protect himself. If the level of defensiveness is less than this self-defense threshold, then the character may cross his arms.

Physical Pain

The pain emotivation is directly proportional to the level of physical pain. Pain in a particular body part will affect the movements involving that body part. We have implemented some body language for pain in the character's head, stomach, hands/arms, and feet. Since the character will have a high compulsion to alleviate his pain, this body language is given a high priority, which will allow it to interrupt any other conflicting body language that has a lower priority.

Pain in the head, stomach, or feet is debilitating. Hence, the character's posture and, if he is walking, the walk speed are both inversely proportional to the level of pain. The character hunches over and slows down as pain increases. If the pain is greater than a certain value, he stops walking altogether. If the character is walking with hand pain, as pain increases, he will gradually stop swinging the arm in pain. For pain in any body part, as pain increases, the character becomes less concerned with any object at which he is looking and more concerned with the body part in pain. Therefore, he lowers his gaze from the current object to the ground in front of him and then, for pain in the hands or feet, moves his gaze to the body part in pain. This gaze change is given a priority level, so that the programmer may override this gazing action if he desires.

For pain in the head, stomach, and hands, if the pain rises above a certain point, the character holds the body part in pain. If he has a headache, he will first place one hand to his head and then, as pain increases, will place the second hand asymmetrically on his head as well. For a stomachache, he will hold his stomach with both hands asymmetrically. For hand pain, he will cradle the injured hand or arm with the healthy one.

5 Evaluation

We performed an informal evaluation of our system, in which we tested twenty-six subjects in a small experiment to gauge the effectiveness of the system. The subjects were given the program with an interface that consisted of seven anonymous sliders that controlled the quantities of the seven characteristics. They were also given a list of possible characteristics. Their task was to move the sliders, view the resulting body language, and match each slider to a characteristic on the given list. Their accuracy was measured by the percentage of sliders that they identified correctly.

The results, shown in Table 1, are encouraging. Accuracy ranges from 62% to 92%. A limitation of this evaluation is the fact that in an interaction with the user, and especially in virtual environments such as in games, the characters will have some context for their actions. We believe that the situational context of this body language is quite important to its identification.

Table 1. Accuracy percentages of the subjects' identification of the various characteristics

Mental	Confidence	Anxiety	Interest	Thought	Anger	Defensiveness	Pain
Accuracy	65 %	85%	62%	77%	92%	88%	88%

6 Conclusion

We have presented a system that allows a developer to endow a character with various personality characteristics, emotions, and mental attributes, such that the character automatically expresses this mental state through his body language. We strongly believe that these affective behaviors increase the believability of the character, which allows the user to better relate to and emotionally connect with the character.

With an emotional connection to the user, applications can affect the user in creative, innovative, and revolutionary ways. Educational games can challenge the player on a personal, emotional, or even ethical level. They can force users to make decisions that shape their personalities or allow them to grow as human beings. Educational applications can teach children values and life lessons. The ability of an interactive agent to personally affect the user undoubtedly allows the agent, and hence the application, to be significantly more effective.

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