Evaluating Emotive Character Animations Created with Procedural Animation

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Abstract. How to create effective body animations for virtual agents with emotions remains the state of the art for human animators and a great challenge for computer scientists. In this paper, we propose to use a model of hierarchal parameters to represent body animations: *emotional*, *style*, *motion,* and *procedural* parameters. Based on this model, we have created motions for a virtual character with generic animation procedures and mapped these procedural parameters into style parameters as proposed in the literature. The expressiveness of the generated animations was verified through experiments in our previous work. In this paper, we further report the results of two experiments attempting to verify how the style parameters are mapped into various emotions. The results reveal that the participants can successfully distinguish emotions based on the manipulation of style parameters for neutral motions such as walking. When these style parameters were used for emotive motions, including pounding, shivering, flourishing and crestfallen, the generated animations were even more effective for intended contexts.

1 Introduction

Modeling and expressing emotions for virtual agents remains a key issue for believability because of the subtleness involved. Most previous research focused on facial expression since it was the most common way to communicate emotions. Nevertheless, body movements are also crucial for the expression of emotion especially in the virtual world where avatars are usually seen in a distance and their facial expressions become too vague to discern.

Not until recent years, the principles used in analyzing human body motions were extended to computer animations for the composition of expressive motions for virtual characters/agents [5]. Nevertheless, the expressiveness of a character animation remains a subjective matter. In recent years, some research in psychology has started to analyze the relationship between motion and emotion (e.g. [6]) but the body

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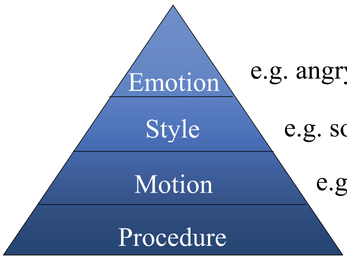


Fig. 1. Hierarchy of parameters for expressing emotive motions

motions used in these experiments were usually performed by professional actors. Therefore, it remains an open question how to generate expressive animations by the computer in a systematic manner in order to deliver emotions to the viewers.

In this work, we aim to design a systematic way to generate human body animations and study the linkage between motion and emotion. We propose to stratify the variables related to expressive motions into four layers: *emotion*, *style*, *motion*, and *procedure* layers with their own respective sets of parameters, as shown in Fig. 1. In the emotion layer, emotions can be modeled with either the basic emotions approach or the dimensional approach [4]. The style layer serves as an intermediate layer for describing the expressiveness of an animation while the parameters specific to a motion are defined in the motion layer. And in the procedure layer, generic animation procedures are used to generate parameterized motions.

In our previous work [6], we have shown that, in terms of style parameters, the expressiveness of an animation can be successfully generated through our animation procedures for walking. In this paper, we investigate how to generate emotive animations by designing appropriate animation procedures for virtual characters and verifying the effectiveness of these generated animations. We conducted two psychological experiments to study the mapping between emotion parameters and style parameters.

2 Related Work

Human body motion always contains subtle emotional ingredients. Wallbott [10] attempted to find the relationship between emotions and body motions by asking motion analyzers to code the characteristics of emotional body movements performed by professional actors. Montepare et al. [6] studied how people of various ages perceive emotions from motions differently. Camurri et al. [2] attempted to find the motion characteristics of expressing emotions in dances. The results of these studies all revealed that human body motions were indeed affected by the emotional states possessed by the human actor.

Most of the studies on the relationship between motion and emotion used professional actors to perform emotional motions for observations. However, in the modeling of virtual agents, it is required to generate these emotive motions by the computer. On the other hand, in the literature of computer animation, there has been much research on analyzing and synthesizing emotional human motions. For example,

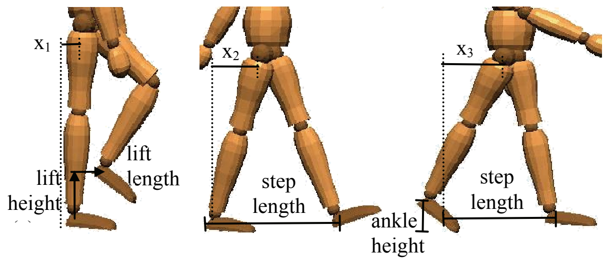


Fig. 2. Definition of the motion parameters for the walking motion

Unuma, et al. [9] used Fourier transform to analyze captured motion clips and synthesized new motions containing various styles. Pelachuad [8] based on a 6-dimesion model to modify gestures of a virtual agent and evaluated its emotional expressiveness. However, for all these approaches, the quality of the final animation relies highly on the quality of the source motions.

Another common approach to the generation of computer animation is by designing parameterized procedures. For example, Bruderlin and Calvert [1] designed a procedure embedded with empirical knowledge to generate the animation of human running. Chi et al. [3] proposed the EMOTE model that made use of the Effort and Shape concepts in Laban Motion Analysis [5] to implement emotional upper-body gestures and full-body postures.

3 Design of Animation Procedures

In this section, we will describe the generic animation procedures that we have implemented to realize parameterized motions for the lower body. We will use the walking motion as an example to illustrate the animation procedures.

The kinematics model that we have used is an LOA1 (Level of Articulation 1) model in the H-Anim standard [11]. We define each branch of the limbs as a 5-bar linkage (including the base) on a plane with four joints. We need to specify at least two constraints in order to uniquely determine this type of mechanism. One common simplification is that we usually make the toes compliant to the ground or parallel to the foot (if it is in the air). Therefore, we need to specify one more constraint to determine the final configuration. According to the type of constraints that we would like to specify in order to determine a key frame, we can classify the procedures for determining the configuration of a leg branch into four different types, each of which is used as a fundamental procedural for composition of a motion.

We use the walking motion as an example to illustrate the generation of a motion with fundamental procedures. We divide the walking motion into three phases separated by three keyframes. In the first keyframe, the two ankles are aligned; the second keyframe is defined when the front leg touches the ground; and the third keyframe is defined when the rear leg leaves the ground. Several motion parameters at various phases are defined to specify the motion, as shown in Fig. 2. These parameters include how the swinging leg is lifted at keyframe 1 (lift_length, lift_height), how two legs are separated (step_length) at keyframes 2 and 3, how the ankle of the rear leg is lifted (ankle_height) at keyframe 2, and how the sacroiliac moves over time (x_1, x_2, and x_3). These motion parameters are used to compute the parameters for the lower-level animation procedures. In addition, the interpolation of in-between frames between two keyframes is performed on the procedural parameters such as joint angles or points in the 3D space.

4 Mapping Motion Parameters into Style Parameters

We have adapted the style attributes defined in [6] as our *style* parameters which originally include *smooth-jerky*, *stiff-loose*, *slow-fast*, *soft-hard*, *expanded-contracted*, and no action-a lot. Since we use only one type of motion at a time, the last attribute (i.e. no action-a lot) is not considered. There could be many ways to map motion parameters into style parameters. Our current implementation is described as follows.

- **Jerky-Smooth:** This parameter is related to the dimension of "fluidity" in [8]. By discretizing the timing curve with different temporal resolution, we can produce different degrees of smoothness/jerkiness.
- **Stiff-Loose:** This parameter is used to specify the stiffness of a motion. We assume that cyclic motions (e.g. walking) are due to a virtual spring embedded in each joint. Therefore, the stiffness can be modeled as the stiffness constant of a spring with a force proportional to its displacement. A stiff joint tends to change acceleration more rapidly than a loose joint.
- **Slow-Fast:** This parameter bears the usual meaning of modifying the tempo or speed of a motion and is related to the dimension of "temporal extent" in [8]. The relative timing between the phases remains fixed.
- **Soft-Hard:** This parameter is related to the dimension of "power" in [8] and is defined on the amount of joint torque (and its angular acceleration) to be applied to each joint. A softer motion results from a smaller torque.
- **Expanded-Contracted:** The parameter is realized by changing the expansiveness of keyframes and is related to the dimension of "spatial extent" in [8].

In our previous work [6], we conducted an experiment to test the effectiveness of the mapping between *motion* parameters and *style* parameters. Participants compared the *target* stimulus (manipulated) with the *standard* stimulus (neutral) and rated the target according to all of the five style parameters listed above. We found that most style parameters are successful except for the soft-hard parameter. As for the ineffectiveness of the soft-hard parameter, we considered a possible explanation that while the zero-order spatial-temporal relationship (i.e. the positions of an object or its displacement) remains fixed, it is difficult to discern second-order changes (i.e. the acceleration of object motion) with human perception. Nevertheless, we have shown that most style parameters have been implemented with satisfactory results on expressiveness.

5 Mapping from Style Parameters to Emotion Parameters

As mentioned above, it is our ultimate goal to have the mapping all the way from *procedure*, *motion*, *style* to *emotion* parameters. For the last step, we need to verify

Table 1. Biserial correlations between style and emotion parameters

style / emotion	jerky-smooth	stiff-loose	slow-fast	soft-hard	expanded-contracted
Angry	-0.24	-0.19	0.27	0.17	0.77**
Fear	0.07	0.61**	-0.56**	-0.01	-0.50**
Joy	-0.11	-0.49**	0.73**	0.06	0.39*
Sadness	0.14	0.43**	-0.73**	-0.04	-0.47**

* $p < .05$，** $p < .01$

the effectiveness of these *style* parameters on expressing various kinds of *emotions*. We follow the basic emotions approach to accept primary emotional responses as *anger*, *joy*, *fear*, *sadness*, disgust and surprise [4]. But we have excluded the last two in this study because the expressions for them depend mostly on facial expressions.

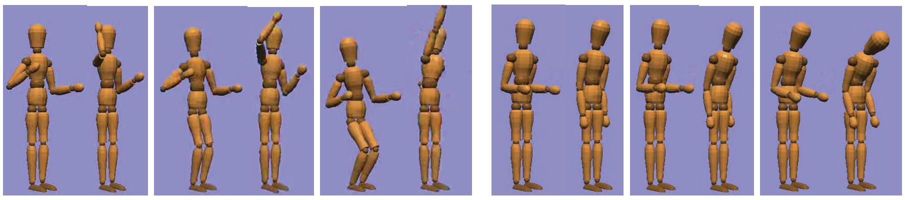
In addition, we regard *walking* as an *emotionally neutral motion*. It means that walking does not relate closely to any kind of emotion.. But we do confront scenarios repeatedly that someone pounds heavily in his rage or that another one flourishes wildly when he is very happy. In other words, there are some kinds of human motions used to express certain emotions. In the present study, we regard *pounding*, *shivering*, *flourishing* and a *crestfallen* posture as *emotional motions* which always come with anger, fear, joy and sadness, respectively. We are not only interested in the expressiveness of style parameters for the emotionally neutral motion of walking but also the adding or canceling effect of these parameters for the emotional motions listed above. To achieve the goal, we designed two experiments.

5.1 Experiment 1: Emotional Expressiveness for Walking

First, we verify the emotional expressiveness of style parameters for the emotionally neutral motion of *walking*. Participants are asked to see two animation movie clips (*standard* and *target* stimuli) shown side by side. The standard stimulus is fixed on all of the five style parameters which are set to the middle range of their intensities. The target stimulus can be one of the 32 (i.e. 2^5) combinations with either high or low in intensity of the five style parameters. Participants need to compare the two stimuli and rate the target from -100 to 100 points to indicate if the virtual character is angry, fearful, joyful or sad (with the standard stimulus as the reference of 0 point).

Thirty-two participants are recruited and the whole procedure is divided into five blocks. The first one is the practice block which is followed by four formal blocks of anger, fear, joy and sadness. The sequence of formal blocks and the presentation of 32 movie clips in each block are set randomly for every participant. Ratings are recorded and then analyzed with biserial correlation.

As shown in Table 1, we have found many significant correlations between *style* parameters and *emotion* parameters. In terms of different kinds of emotions, we can see that anger correlates with only the extend of body expanding while other three basic emotions correlate to stiffness, speed and expanding significantly with different patterns. For example, when the character is fear, its body movement is stiffer, slower and more contracted. On the contrary, when the character is joyful, its movements are more relaxed (loose), faster and more expanded. However, when the character is sad, it will become stiff, contracted and even slower in motion than its fearful reaction.



weak mild strong weak mild strong
(a) joy motion (b) sadness motion

Fig. 3. Examples of emotive motions with different strengths for joy and sadness

Table 2. Ratings of emotive motions by compatibilities of style parameters

emotion strength	mean	stdev	emotion strength	Mean	stdev
angry (incompatible)	35.3	11.5	joy (incompatible)	25.7	12.1
(compatible)	78.9	10.8	(compatible)	85.4	10.4
fear (incompatible)	37.4	15.4	sadness(incompatible)	42.4	10.2
(compatible)	86.8	13.8	(compatible)	68.1	10.3

5.2 Experiment 2: Emotional Expressiveness for Other Motions

Next, we continue to evaluate the adding or canceling effects of style parameters for some emotional motions. We use *pounding* as the typical motion for anger, *shivering* for fear, *flourishing* for joy and a *crestfallen* posture for sadness (Fig. 3). In the movie clips of this experiment, the virtual character starts to talk with some one invisible for a few seconds and then ends up with a particular emotional motion. Participants have to rate the degree of the character's anger, fear, joy and sadness under the conditions of pounding, shivering, flourishing and crestfallen, respectively.

As for the manipulation of style parameters, we design two versions of animations, either *compatible* or *incompatible*, for each emotional dimension. For example, according to the results on Table 1, more expanded motion is compatible with anger while more contracted motion is incompatible with it. For the same reason, motions high in stiffness and low in speed and expanding are compatible with fear while motions with the opposite pattern of style parameters are incompatible. The same rule can be used on the condition of sadness, too. However, for the sake of joy, the motion needs to be low in stiffness and high in both speed and expanding to be compatible.

Thirty-four participants are recruited to compare the target stimulus with the 50-point standard stimulus and rate the character's emotions from 0 to 100 points. The results are summarized on Table 2. For all of the 4 emotional dimensions, compatible conditions always lead to higher ratings of target emotions. We have also verified the effects with *t*-tests between compatible/incompatible conditions and all of the tests are significant with the standard of $p<0.01$. It means that the style parameters can actually have their adding effects on emotional motions.

5.3 Discussions

Based on the results of these two experiments, we can see that three but not all of the five *style* parameters are significantly related to the *emotion* parameters with different patterns. And whether the motions are emotionally neutral or not, the style parameters work as well. The inefficiency of jerky-smooth and soft-hard can be due to the same reasons that we have discussed in Section 4 previously. But it can also be possible that these two style parameters do not matter at all. We need more studies to find out the answer. But up to now, we do have satisfactory results of the mapping from procedure, motion, style to emotion parameters. That is to say, we have verified the emotional expressiveness of the lower-level parameters in our hierarchical model.

6 Conclusions

The objective of our research is to study how to generate emotional animations for virtual agents with a systematic procedural approach. The expressiveness of these animations is determined by the appropriate design of parameters at various abstraction levels. In this paper, we have proposed and implemented such a design and conducted two psychological experiments on human walking and other motions to verify the expressiveness of these parameters. Based on the two experimental studies and previous works, we conclude that three out of five style parameters are implemented with satisfactory expressiveness. We believe that the current work can lead to various applications such as an emotive virtual character on the interactive television. We also believe that this work is one step toward the establishment of affective computers [8] which can recognize, express and even have emotions. We will continue to pursue these two lines of developments, both applicative and theoretical, in the future.

Acknowledgement

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