PEIBM- Perceiving Emotions using an Intelligent Behavioral Model

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Abstract**—**Computer animation is a widely adopted technique used to specify the movement of various objects on screen. The key issue of this technique is the specification of motion. Motion Control Methods are such methods which are used to specify the actions of objects. This paper discusses the various types of motion control methods with special focus on behavioral animation. A behavioral model is also proposed which takes into account the emotions and perceptions of an actor which in turn generate its behavior. This model makes use of an expert system to generate tasks for the actors which specify the actions to be performed in the virtual environment.

Keywords**—**Behavioral animation, emotion, expert system, perception.

I. Introduction

COMPUTER animation has long been used to give a sense of realism in computer-generated sequences. The animator has always wanted to incorporate movement of the characters and objects in such a way that they would behave as realistically as possible. This involves the use of imagination, supposition and prediction of how a particular object would act and react in a certain environment.

Animation methods may be used to add motion control to various objects. This motion control includes the understanding of physical laws and the emotions exhibited by the actor which affect the actions of an object.

It is believed that "motion of objects is planned at a task-level and computed using physical laws" [2]. This paper describes a model for a behavioral animation system. This model allows the specification of emotions for virtual actors enabling them to exhibit autonomous and life-like behaviors.

The structure of this paper is as follows: Section 2 describes some related work in this field. In Section 3 Motion Control Methods are defined. Section 4 gives an overview of the proposed intelligent behavioral model –PEIBM. Future work and the main conclusions of this effort conclude the paper.

II. Related Work

The use of behavioral animation in generating computer animation is a well explored domain. Reynolds [1987] described the first use of a behavioral model to produce a flocking behavior. Terzopoulos et al. [1994] and Tu *et al.* [1994] created autonomous fishes living in a physically modeled virtual marine world. Unuma *et al.* [1995] modeled human figure locomotion with emotions.

Other papers presented interactive systems involving virtual creatures. Maes et al. [1995] designed a full-body interaction system with a virtual dog. Perlin [1995] described virtual actors' seemingly emotionally responsive using random noise functions.

Research in autonomy has also focused on social behaviors. Mataric [1995] extended Brooks work to create complex group behavior produced from simple local interactions. Béheiraz et al. [1996] presented a model of nonverbal communication and interpersonal relationship between virtual actors. The Oz project [Bates 1994; Reilly 1996; Loyal *et al.*, 1997; Mateas, 1997] focused on the creation of believable autonomous agents that exhibit rich personalities in interactive dramas.

III. Motion Control Methods

Thalmann [2] has specified classification of computer animation using synthetic actors, the motions they exhibit and the interactions between such actors."A *motion control method* specifies how an actor is animated and may be characterized according to the type of information to which it is privileged in animating the synthetic actor." [2]

Basically, motion control methods are used to specify the movements of synthetic actors which vary with the type of information that is used to animate them. This privileged information has been classified in 3 main categories:

1. geometric animation
2. physical animation
3. behavioral animation

A. Geometric Animation

This type of animation deals with geometric data which is used to specify the local definition of motion for an actor. Motion is usually defined in terms of coordinates, angles, and other shape characteristics. Key areas under this field include *performance animation*, *shape transformation* and *parametric keyframe animation*.

B. Physical Animation

In this type of animation, the animator has to provide physical data. The physical characteristics correspond to the physical forces, such as mass, torque, gravity and force, which affect the motion of an actor. The physical laws help control skeletal motion, which have an important application in calculating deformations of bodies and faces [6]. *Dynamic* *simulation* comes under physical animation.

C. Behavioral Animation

This type of animation takes into account the relationships that exist within the various actors. It models the behavior of characters including complex emotional interactions between them. Such type of animation is required because the 'manner' of movement of a character needs to be modeled. This type of animation is the most difficult to model as a "more or less element" is involved. *Task-level animation* is used to specify how animations are controlled.[1]

1) Task-level Animation

Animation is in task-level when the behavior of objects is given in terms of relationships and events. Actions in such an animation systems are specified only by their effects on objects. Typical tasks may include:

- Walking from a point A to a point B
- Picking up an object from location A and moving it to location B
- Speaking a sentence

a) World Modeling

In this phase, the geometry of the object and the physical characteristics of a synthetic actor are specified. Valid motions for an actor are governed by the occurrence of obstacles in the environment which become constraints for the motion of the actor. The primitive capabilities of a synthetic actor also need to specified e.g. joint limits [3].

Such models are attribute-based as the scene, the objects in the scene and the actors participating in the scene, all have attributes.

b) Task Specification

Tasks can be specified in three ways [3]:

- *by example:* The operator needs to perform the task at least one to gain a better understanding of its working. This approach is suitable for robotics.
- *by a sequence of model states:* A sequence of model states is given. Each state is configured according to the objects in the surrounding environment. The main disadvantage of this approach is that these relationships need to be specified using equations which maybe difficult to solve.
- *by a sequence of commands:* The movements of the actor are specified broadly and the system fills in the details [3]. These movements maybe specified at different levels of abstractions depending upon the animators' capability and the detail he requires. E.g.

WHEN (DancerB Touches) WALK VERY SLOWLY TO LEFT FRONT UNTIL (Edge of Stage)

[1] Since this paper focuses more on behavioral modeling, it is imperative to define the techniques associated with it in more detail. The techniques for the other two types of motion control methods can be found in [2] and [3].

c) Code Generation

For an animation system, the output at this phase may occur in various forms [3]:

- The complete animated sequence under the form of a series of frames ready to be recorded;
- The value of parameters of each frame, allows easy calculation for a parametric keyframe animation system;
- The value of parameters for certain keyframes, allows easy calculation for parametric interpolation;
- A script in an animated language; and
- A script in a command-driven system

d) Walking Task

For the generation of such a motion, many things need to be considered including the obstacles and nature of the terrain. The following elements are to be incorporated [3]:

- Obstacle avoidance
- Locomotion on rough terrains
- Trajectory planning
- Kinematics and dynamics

e) Grasping Task

This task uses inverse-kinematics. The joint angles of an actor are determined from the position of the tip of the hand and the position of the object to be grasped [3]. The following elements are to be incorporated [3]:

- Path planning
- Obstacle avoidance
- Stability and contact determination
- Kinematics and dynamics

f) Talking Task

For this task, sentences are analyzed and broken down into phonemes, facial expressions are then selected and expressed as face deformations caused by muscles: jaw opening, eye opening, face folds, etc. [3]. The following elements are to be incorporated [3]:

- Phonemes detection
- Selection of facial expressions
- Handling of facial parameters
- Animation generation

IV. PEIBM – AN INTELLIGENT BEHAVIORAL MODEL

The environment in which an actor exists is unpredictable. The actor should be independent. It must be able to perceive its environment and decide what to do to reach the goal defined by its behavior [7]. Thus, the design of a behavioral animation system should allow autonomous actors to be capable of perceiving their environment, expressing their emotions, transforming them into believable behavior and generating appropriate actions for this behavior.

They should appear spontaneous and they should make the audience believe that an actor is alive and has its own will. As stated by Bates [1994], believability of an actor is made possible by the emergence of emotions clearly expressed at the right moment. It is very important to specify the emotions of an actor to make its appearance as realistic as possible.

The behavioral model shown in Figure 1 provides a tool meeting the above specified needs and allows an animator to create virtual actors expressing autonomous and believable behaviors. PEIBM makes use of an expert system which uses perception and the emotions generated in response as input. This system then intelligently specifies the tasks (actions) including emotions for the actor.

PEIBM is composed of four modules: Perception, Emotion, Behavior and Action. The rest of the paper describes different parts of the behavioral system.

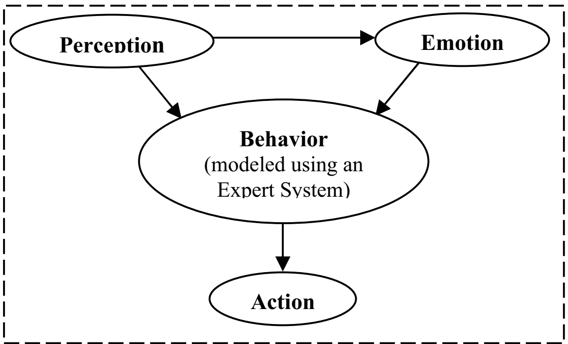

Figure 1: PEIBM – Perceiving Emotions using an Intelligent Behavioral Model

A. *Perception*

The appropriate actions of an actor can only be specified if the system knows the state of the environment of the actor. However, whatever actions an actor performs involve objects or other actors. These actions of an actor may in turn also cause some events. Therefore, perception is decomposed into three categories [7]:

1. Perception of objects and actors,
2. Actions of actors, and
3. Events.

An actor's perception may include only the objects and the other actors in its neighborhood. But this restricts all possible behaviors for this actor because only the presence and the characteristics of an object or an actor are used to select a behavior. Thus, the perception module should then produce three types of perception.

- *perception of objects:* presence of objects and actors.
- *perception of actions:* actions of actors.
- *perception of events:* actors performing actions on objects.

Perception of events is more complex. Events can further be decomposed into three types: desirable events, events happening to another actor, and potential events which may or may not occur.

Now the question arises of how this perception is captured. The perception of an environment and the characteristics of an object, an actor or an action cannot be done easily from their 3D representation. Actions cannot be captured through motion capture as well. The only solution possible is by categorizing every object, actor and action based on its nature and characteristics.

B. *Emotion*

Emotion may be defined as a state of feeling, a psychic or physical reaction (as anger or fear) subjectively experienced. It maybe a strong feeling and physiologically involving changes that prepare the body for immediate vigorous action [8].

"An emotion is an emotive reaction of a person to a perception" [7]. This reaction might be a body response, a facial expression, a gesture or some other specific behavior. Two different persons can thus have different reactions to the same perception according to the way they are affected by this perception.

Like the perceptual model, the emotional model of an actor also generates emotions belong to three classes. The emotions are generated, again, in reaction to objects, actions of agents and events. The class of emotions caused by events is partitioned into three groups of emotion types [7].

1. The first group concerns the emotions caused by potential events.
2. The second group concerns events affecting the fortune of others, and
3. The third one concerns events affecting the well-being of the actor.

$em_{pot} \in [0..1]$

$em_{\theta} \in [0..1]$

$em_i \in [0..1]$

if cond(*perception*)

  $em_{pot} = f_{perc}(perception)$

else

  $em_{pot} = 0$

if $em_{pot} > em_{\theta}$

  $em_i = f_{perc}(em_{pot})$

else

  $em_i = 0$

$em_i = (em_{pot} - em_{\theta}) / (1 - em_{\theta})$

Figure 2. Computation of an emotion [7][2]

Becheiraz *et al*. [7] have computed emotions using threshold values.

The same theory is applied to the emotional model here. Emotions for an actor are computed using two variables; emotion potential and emotion intensity. An emotion potential is computed from the group of elements (perceptions) contributing to the emotion. If the potential crosses a given threshold, then its value is used to compute the emotion intensity. This threshold corresponds to the minimum intensity of the potential for an actor to feel the emotion. The computation algorithm is given in Figure 2.

A threshold value of 0 always allows the generation of an emotion, while a value of 1 never allows an emotion to

[2] The potential of an emotion *em* is denoted as *empot*, its threshold *em*q and its intensity *emi*. 0 indicates maximal value and 1 indicates minimal value.

emerge.

C. Behavior

"Behavior is often defined as the way in which animals and humans act, and is usually described in natural language terms which have social, psychological or physiological significance, but which are not necessarily easily reducible to the movement of one or two muscles, joints or end effectors". Behavior is also the response of an individual, group, or species to its environment [8].

Behavior may be described in a hierarchical way. The behavioral model decomposes a behavior into simpler behaviors that may themselves be decomposed into other behaviors. Each level of this hierarchical decomposition contains one or more behaviors, which are performed either sequentially, or concurrently.

This behavior has been modeled by means of an expert system. An expert system is a computer program that contains a knowledge base and a set of algorithms or rules that infer new facts from knowledge and from incoming data. The degree of problem solving is based on the quality of the data and rules obtained from the human expert. The expert system derives its answers by running the knowledge base through an inference engine. For PEIBM, Prolog has been used as an inference engine. It is a software program which interacts with the user and processes the results from the rules and data in the knowledge base. It uses the data driven approach (forward chaining). In this approach, the system keeps track of the current state of problem solution and looks for rules which will move that state closer to a final solution.

All emotions and perceptions of the actors are represented in this expert system. It also includes rules for specifying the physical characteristics of the actors, the joint angles, the orientation of material objects, etc.

D. Action

The action module manages execution by using a task specification language. This language extracts the goals and the sub-goals from the expert system and subsequently executes the tasks on the concerned actor thus making it autonomous.

For this purpose, a task-specification language has been used. For example, if we have to perform the operation:

Put GLASS **on** TABLE

Assuming that our task specification language has this set of task commands:

Walk to <location>
Pick up <object>
Put <object> **on** <object>
Sit down

This will be executed as:

Walk to BAR
Pick up GLASS
Walk to TABLE
Put GLASS on TABLE

Such a sequence of steps can only be executed if the knowledge base has the following facts:

ABOVE (GLASS, BAR)
SITDOWN ()
SMILE (number)
FROWN (number)

[*number* represents the intensity specified in the emotional model which can be mapped on the autonomous actors' actions]

V. Conclusion and Future Work

This paper has presented an intelligent behavioral model for specifying the emotions and perceptions of autonomous actors. PEIBM makes use of expert systems designed in Prolog which specify the rules needed to describe the behavior of the actors. It also makes use of a task specification language which extracts these emotions from the expert system and models them to specify appropriate action of the actors.

Although, the work presented is in a preliminary stage, it can be extended to include neural networks for the specification of emotions and perceptions. A better task specification language can also be designed which takes into account the use of sub-algorithms to generate shorter tasks.

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