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Modelling Emotional Behaviour in Virtual Crowds through Expressive Body Movements and Emotion Contagion

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Abstract

Virtual crowds are gaining more relevance in computer graphics. Research in this area has been of great interest for both industrial and scientific activities related with entertainment and virtual simulation, and nowadays it is possible to generate virtual crowds with believable and complex behaviour. However, expression of emotion and social behaviour for multiple characters is a research area that still remains to be further investigated. Particularly, emotional awareness and emotion contagion between artificial agents is gaining more interest in recent years. In this paper we present a work-in-progress that deals with the current state-of-the-art of emotional virtual crowds, and we present an overview of a computational model capable of generating virtual crowds with body emotional behaviour and emotion contagion. Also, we present a brief overview of a perceptual study in relation to the perception of social behaviour in virtual crowds. Our work seeks to shed more light into this area of computer graphics and to find new paths of research for future work.

Categories and Subject Descriptors (according to ACM CCS): Computer Graphics [I.3.7]: Three-Dimensional Graphics and Realism—Animation Computer Graphics [I.3.7]: Three-Dimensional Graphics and Realism—Virtual Reality;

1. Introduction

In recent years, virtual crowds have gained an increasing research interest. The existing capabilities to create high-fidelity crowds allow for the generation of realistic and complex virtual worlds in real-time, but a challenging topic issue remains in regards with the behaviour of virtual crowds, especially emotional behaviour and social interaction. Considering the enormous complexity of crowds, this behaviour goes further beyond path-finding and local avoidance [TGMY09]. Social and emotional behaviours are two important aspects in relation to this [MMSN09], particularly the emotional awareness and the emotion contagion between artificial individuals [PDP*11].

Modelling better computational models for behaviour in virtual crowds, specially emotional behaviour, is of great interest not only in the areas of special effects and virtual realism related with films and video-games, but also in simulation of crisis-management where crowds play a core role, such as simulation of panic situations or emergency evacuations. Emotional contagion, defined as the tendency to catch another person's emotions [HTC94], has great importance in psychology and sociology as well, and several studies have proven the significance of this contagion effect in the way humans and other species behave, which gives more importance to the seek of better computational models dealing with this phenomenon.

In this paper, we present our work-in-progress related with emotional crowds. In the next section (Section 2) we present an overview of the state-of-the-art in the areas of emotion and virtual agents. In Section 3, we explain the process of generating an emotional virtual crowd, including the way we animated the characters from motion capture technologies and the description of a prototype of an emotion contagion model based on the work of Pereira et. al. [PDP*11]. We also include a brief overview of a recent perceptual study in Section 4, which serves also as an use example of our model, in this case with the purpose to investigate the effects in perception of contextual background crowds [RCQP]. Finally, in Section 5 we conclude with final remarks and open paths of research in these areas.

Figure 1: *Androgynous mannequin models composing the virtual crowd.*

2. State of the art

Extensive research has been done in the simulation of virtual agents and crowds [Rey87, MT97], including artificial behaviour for collision avoidance [GCK*09] and autonomous agents [ST07]. Also, there have been recent research regarding the perception of crowds in relation to emotional expression [EHEM13] and body language [PEE13]. More recent studies have investigated the generation [HMBP05] and mapping [CMPM12] of expressive motions between artificial agents and real people.

Emotion contagion has been widely investigated in relation to the theory of this phenomenon and its implications in human behaviour [HTC94]. Particularly for virtual crowds, there have been several efforts in developing generic computational models to simulate the effects of emotional contagion between artificial individuals [LLB11, PDP*11].

We continue in the next section by describing the process for creating the virtual crowd and its emotional behaviour.

3. Crowd generation

Since our work focuses in full-body motions of characters, we used a simple model of a free androgynous mannequin (see Figure 1) which was available from the online assets database TurboSquid. We chose this model since it did not include facial expressions or other details (for example, finger motion). In order to identify the direction of the face more easily, the original model was slightly modified by adding a small nose to its head.

The virtual crowd was generated in the Unity engine replicating the androgynous mannequin presented above. For the composition of the crowd, we considered two different types of characters: static small groups and mobile individual walkers (See Figure 1). Mobile characters were steered using an A* Pathfinding implementation and a graph-mesh with static way points and several destiny nodes.

3.1. Annotated affective data corpus

For the emotional animation of the virtual crowd, we used two annotated motion-capture libraries based on acted emotions: the Carnegie-Mellon Graphics Lab Motion Capture Database and the UCLIC Affective Posture and Body Motion Database [KDSBB06], both databases of acted expressions recorded with a VICON motion capture system. These databases included an extensive collection of emotional animation based on full-body motion. These animations were imported into 3D Studio Max, where they were mapped to the skeleton of the mannequin model and then exported to the Unity game engine.

We focused the emotions of virtual agents concerning just happy and sad full-body emotional expressions, two of the six Ekman basic emotions [Ekm92], in addition to a neutral emotional expression (See Figure 2).

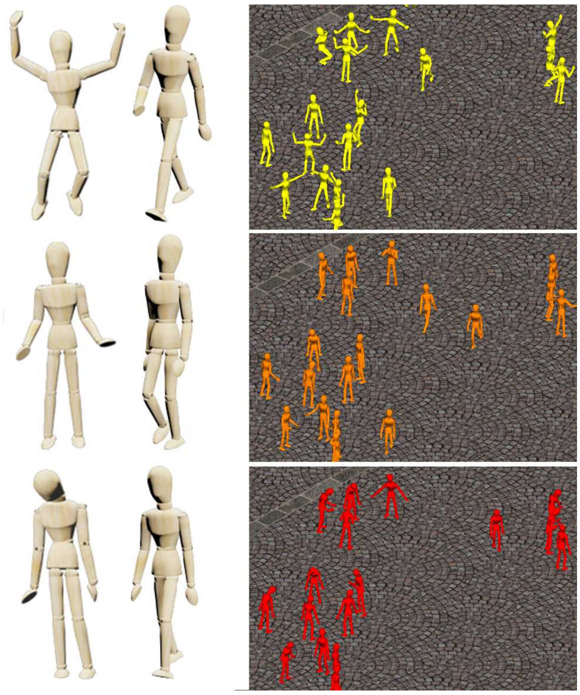

Figure 2: *Standing and walking characters of the crowd displaying happy (above), neutral (middle) and sad (below) full-body motion behaviours. The agents in the crowd were coloured automatically according to their emotion.*

The animations were selected from the motion-capture libraries using the annotations provided by their authors, and the transitions were blended with Mecanim (Unity's animation system) using finite state machines. We run a pre-study based on a perceptual experiment to confirm the correlation between each animation and each mood (See Section 4).

3.2. Emotion contagion

The emotional behaviour of the crowd was integrated at the individual agent level, and the model presented here is a simplification of a previous work on this area [PDP*11].

To define the emotional state of each agent, we defined a one-dimensional scale in the range [-1, 1] to represent each of the three moods that the model uses, being -1 sad, 0 neutral and 1 happy. The animation transitions between the emotional states were blended according to this scale. We also defined an additional parameter to probabilistically determine the susceptibility of contagion. Higher percentages imply more probabilities of being susceptible to catch others emotions. Thus, each agent was represented by the tuple <*e, s*>, being *e* the current value of its emotional state and *s* the probability of being emotionally affected by others.

The changes in mood inside the crowd emerge from the emotional awareness between agents, which is based on the emotional contagion model. With this, each agent is able to perceive, appraise and react to others emotions according to the three modules that compound the model: the *perception module*, the *appraisal module* and the *contagion module* (see Figure 3).

3.2.1. Perception module

To implement the *perception module*, a field of view (5 meters in scale) was defined for each agent to represent what the character sees and its field of awareness of others emotions. The perception occurs when an emotional agent, i.e. character A, intersects with the field of view of another agent, i.e. character B. When this happens, character B receives the value *e* of the emotional state of character A.

3.2.2. Appraisal module

Once an agent B has perceived the emotion of another agent A, the next step is handled by the *appraisal module*. At this stage, there is an evaluation to check the possibilities of emotional contagion. This evaluation is made through the susceptibility parameter *s* of the agent B. Through a random function based on an uniform distribution (*random()*), the module calculates a real number between 0 and 1 and compares it with the parameter *s*. The agent B will be affected by the mood of the agent A if *random() < s*.

To prevent loops and make the behaviour of the crowd more believable, after each evaluation and after any possible contagion, agent B sets a time lapse *t* in which it will be immune to emotional contagion.

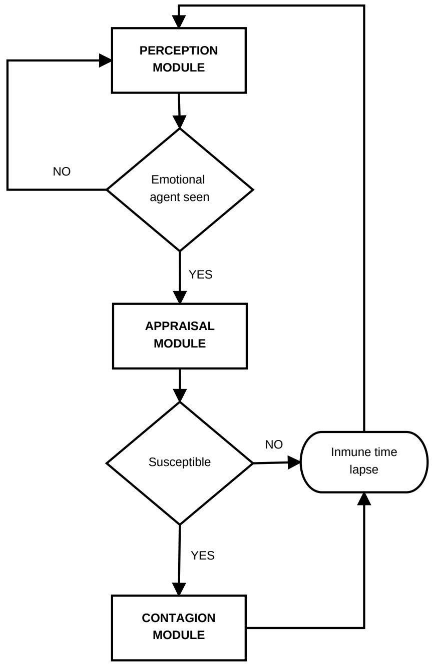

Figure 3: *Emotional contagion model diagram.*

3.2.3. Contagion module

In the last step, if the susceptibility was positive in the previous module, then contagion occurs, and the *contagion module* handles the change of mood. In this module we implemented two alternative approaches: 'strong contagion' and 'contagion by steps'.

In the first approach (strong contagion) the character that has been affected simply copies the value of the emotional state of the agent perceived, converging both emotionally. Thus, for example, if a happy character (1) is affected by a sad character (-1), the happy character will change its emotional state to sad (-1).

The second approach (contagion by steps), is less aggressive in terms of contagion, and in this case the emotional state of the character affected is moved one step down/up (-1/+1) in the one-dimensional mood scale, depending on the emotional state of the character perceived. In this case, if a happy character (1) is affected by a sad character (-1), the happy character will change its emotional state one step down, in this case, to neutral (0).

4. Perceptual study

With the virtual crowd model described in the previous section, we did a series of user studies to provide feedback for the computational model and to investigate different aspects of perception of emotions in virtual social context. We created several video scenes portraying virtual crowds and we asked participants to rate the mood of them on a five point Likert scale (from 1 = negative to 5 = positive, where 3 = neutral). Specifically, in one of the experiments, participants (22M:6F) were asked to rate the mood of each of the three emotional animations to independently verified that the sad, happy and neutral animations were perceived as such when mapped onto the specifics of our characters. This study helped us to confirm the correlation between the animation of the motion-capture databases and the mood that we were intending to convey in each of the scenes.

In addition to this, more complex experiments were done regarding contextual aspect of virtual crowds. In a recent study, we investigated the effects of a background virtual crowd in the perception of the mood of several scenes [RCQP].

In the next section we present some ideas of future work in relation to these perceptual studies.

5. Future work

In this paper, we focused on the implementation of emotional behaviour in virtual crowds in terms of body movements and, specifically, in emotion contagion. The phenomenon of emotional contagion still needs to be further investigated, but the model presented here can be used as a base of more complex implementations. We can defined several paths of potential improvement. In our work we have just considered three emotional states (happy, neutral, sad), but the consideration of more complex emotions, such as anger or panic, could lead to a much better computational model and more realistic behaviour for virtual crowds. Also, it could be interesting to consider a more complex appraisal module with history of previous contagion for each character and with non-static susceptibility values. In relation to the mood scale, more efforts could be put in the representation of the emotional state of each agent through non-discrete values or multi-dimensional mood scales.

With respect to further uses of this model, there are a number of potential user studies that can be done in order to investigate different aspects of crowd behaviour and how people perceive it. The study mentioned in Section 4 is an example of a study regarding the effects of virtual crowds in different scene contexts, but other experiments related with perception in panic situations or during mood changes could lead to very interesting results as well. Also, immersing the participants with the virtual crowd through virtual reality could also be an exciting area of investigation that could open many interesting paths of research in the area of simulations, video games and special effects.

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