An Emotion Model of Virtual Human In Emergent Events *

Abstract

Emotion can influence human behavior and action, modeling human emotion is very important in many fields. Based on the previous researches, a new emotion model of virtual human in emergent events is presented. The parameters of a virtual human are proposed, the model considered the emotion contagion and integrated personality; some formulas are illustrated for human escaping in earthquake, the result shows that the model can closely simulate the emotion process in emergent events..

1 Introduction

A Virtual human is a 3D graphics entity with artificial intelligence models, early virtual human had no autonomy, their movements were controlled by the design of animators. In recent years, artificial intelligence has greatly influenced the development of virtual human, modeling emotion model of a virtual human is a new research branch in virtual reality. The casualties' quantity of whole world in natural calamities or accidents is still in a high level, in many emergent events, most people behave emotionally, a few can keep calm, people escape from dangerous area, emotion contagion can enhance confusion in a crowd and can result in a trample accident.

In order to reduce the casualties in accidents, the public should master escaping skills in emergent events. there is a growing concern on modeling virtual human in safety education. Emotion simulation can help people to predict possible escaping scene in emergent situation. The current researches on crowd evacuation seldom considered emotion parameters, we should integrate emotion into the evacuation models.

An emotion model of virtual human is set up in the paper, we illustrate the model in an earthquake escaping from a building and a crowd on a bridge. When an earthquake occurs, most people can perceive dangerous environment, they will escape from a building with hope and fear emotion state, when they are inside the building, many people construct a crowd, emotion can propagate from one person to others; when they are outside the building, the effects of emotion contagion will decrease, different person will have different emotion intensities.

2 Relative Research On Emotion Model

Emotion plays an important role in human behavior decision and action, Darwin published the first book on emotion research [Darwin, 1872], and he thought that human emotion is a communication method in human society. There are a lot of emotion models in psychology, but many of them are not computational. In recent years, with the development of computer technology, building computational emotion models is a hot topic. Ortony et al. presented the famous OCC theory of emotion [Ortony et al.,1988], they thought that an emotion is a cognitive appraisal for an event, an agent or an object. They gave a computational emotion structure. In fact, many emotion models are based on OCC model, for example, the OZ project at CMU made a lot of research on emotion and personality for believable agents [Bates,1994]. Picard summarized the previous research on emotion, she presented the contents of affective computing [Picard.,1997], and emotion model for virtual humans is a branch of affective computing. El-Nasr et al. proposed a rule-based emotion model, the model could mapped the evaluation from events to emotional intensities [El-Nasr et al., 2000], Badler et al. adopted finite state machine to control a virtual human's behavior, they used locomotion parameters to control virtual human's emotional pose movement [Badler et al., 1997][Chi D et al., 2000] . Sun et al. constructed a hierarchical fuzzy rule-based system to model personality and emotion for a story character [Su et al., 2007].Gratch et al. presented the EMA emotion model by cognitive appraisal theories, the model includes domain-independent algorithms of cognitive appraisal [Gratch et al., 2004] [Stacy et al., 2009]. Lim et al. proposed the FAtiMA-PSI architecture to model autonomous agents, the model balanced the physiological cognitive dimensions for creation of life-like autonomous agents [Lim et al., 2009]. R.Prada et al. developed a model to support group dynamics of autonomous synthetic characters by social psychological sciences [Prada et al., 2009] .

Emotional contagion refers to the process whereby the moods and emotions of those around us influence our own emotional state [Hatfield et al., 1994][Janice,2008], there are little research on computational emotion cognition for crowd behavior, in the process, people can transmit their emotions to others with non-verbal manner. Bosse et al. gave a model of emotion contagion, but it not for crowd behavior animation, they used an agent-based approach to formalize and simulate emotion contagion spirals within groups [Bosse et al., 2009]. Other researches on emotion contagion are mainly based on appraisal emotion theory [Aydt et al., 2011] [Barsade, 2002] [Bispo et al., 2009], but the models are not suitable for a larger scale crowd in emergent situation, how to drive emotion contagion in a crowd is still a problem.

Scoail force model did not consider parameters of a crowd [Helbing et al., 1995], F.Durupinar et al. proposed approach maps these parameters to personality traits [68]. It extended the HiDAC (High-Density Autonomous Crowds) system by providing each agent with a personality model based on the Ocean (openness, conscientiousness, extroversion, agreeableness, and neuroticism) personality model. Each trait has an associated nominal behavior [Durupinar et al., 2011] . Shao et al. used cognition model to guide a pedestrian's motion in urban environments, they built the environment using hierarchical data structures, which efficiently support the perceptual queries that influence the behavioral responses of the autonomous pedestrians [Shao et al., 2007].

From the above review, many emotion models are for individuals, there is little research on interdisciplinary fields of crowd emotion and behavior animation. We hope to find a new method to integrate emotion parameters into crowd animation.

3 Crowd Emotion Model

Let VH_i represents the *i* th virtual human, the virtual human has the following parameters :

(1) The mass of VH_i is defined by m_i , r_i is the radius of VH_i.
(2) The direction of VH_i is defined by $\boldsymbol{DIR}_i$, it is a vector.
(3) The velocity of VH_i is defined by V_i,
(4) The exit perception value of VH_i is defined by PE_i, if PE_i=1, VH_i can perceive the exit position; if PE_i=0, VH_i can not perceive the exit position.
(5) The perception region for moving objects is defined by PRS_i ,the region is a sector with the radius RO_i and angle AO_i (AO_i is 120 angular magnitude in the paper).
(6) The perception region for other emotion is defined by PRE_i, the region is a sector with the radius REO_i and angle AO_i , $REO_i< RO_i$.
(7) The current location of VH_i is defined by L_i.
(8) The personality sets of VH_i is defined by $\boldsymbol{PS}$, PS_i is a personality variable. $\boldsymbol{PS}=(Po,Pc,Pe,Pa,Pn)$, Po,Pc,Pe,Pa,Pn are personality value in OCEAN personality model (the personality variable are openness, conscientiousness, extraversion, agreeableness, neuroticism), all the values are in the [0,1] interval. Personality is a kind of attributes that manifests in normal life. It is difficult to use accurate data to describe the personality impacts on group events.In the paper, N-type is neuroticism, the C-type is conscientiousness, and O (E,A)-Type is openness, or extraversion, or agreeableness.
(10) The emotion intensity of VH_i is defined by EI_i, it represent the inner emotion state.
(9) The emotion expression intensity of VH_i is defined by EP_i, it represent the outer emotion expression, it is related to personality vector.
(10) The receive level value of emotion cognition from others is defined by RC_{ji}, it is in the [0,1] interval. It represents the receive ability of emotion from VH_j to VH_i. If it is equal to 0, VH_j can not influence the emotion of VH_i . if it is equal to 1, VH_j can easily influence the emotion of VH_i.
(11) The level value of the virtual human sends emotion to others is defined by SD_{ij}, it represents the emotion influence ability from VH_i.to VH_j, it is in the [0,1] interval. If it equal to 0, VH_i cannot influence the emotion of VH_j. If it is equal to 1, VH_i can easily influence the emotion of VH_j.
(12) The perception intensity for emotion cognition is defined by PEI_{ji}, it represents the emotion perception ability of VH_i to VH_j. If it equal to 0, VH_j can not perceive the emotion of VH_i. If it equal to 1, VH_j. can easily perceive the emotion of VH_i.

In emergent situation, a virtual human perceives dangerous information in a virtual environment, the safety motivation will drive a virtual human's emotion behavior, in the following steps, any person can perceive the exit location, the emotion contagion process is simulated by the following steps:

(1) Set up the initialisation of all virtual human's parameters;
(2) Consult all L_i, detect collision to static obstacle; detect whether the exit is in the PRS_i, move to the near exit.
(3) Calculate the emotion contagion value in PRE_i, update emotion expression intensity;
(4) Move to the person with the biggest emotion expression intensity in PRE_i.
(5) If a virtual human is just in the corner of exit or wall corner, change its direction.

For the virtual human VH_i, the emotion contagion DEP_{ji} from VH_j to VH_i is calculated by the following formula:

$$DEI_{ji} = PEI_{ji} * RC_{ji} * SD_{ji} \quad (1)$$

PEI_{ji} is related to the distance between two virtual humans, let $ds(ji)$ is the distance from VH_j to VH_i, if VH_j is in PRS_i, PEI_{ji} is calculated by the following formula:

$$PEI_{ji} = [1 - 1/(1 + e^{-ds(ji)})] * EP_j \quad (2)$$

The update inner emotion intensity of VH_i is as the following formula:

$$EI_i = EI_i + \sum_{j=1}^{N} DEI_{ji} \quad (3)$$

And the outer emotion expression intensity is calculated by the following:

$$EP_i = EI_i * f(PS_i,) \quad (4)$$

All $f(PS_i,)$ are in [0.1].

We can select the virtual human with maximum EP_i as the leader in PRS_i,For the leader, its emotion expression intensity $EPL(PRS_i)$ is as the following:

$$EPL(PRS_i) = \max \sum_{j=1}^{N} EP_j, (j \in PRE_i) \quad (5)$$

For all the follower of the leader, we design an emotion force F_{leader}, it can drive the virtual human follow the leader, let ***dir*** is the direction to the leader, *dir_length* is the distance to the leader, F_{leader} is caculated by the formula:

$$F_{leader} = dir * EP_i * e^{-dir\_length} * M_i * \lambda \quad (6)$$

λ is a coefficient.

Based on Helbing's social force model [Helbing et al., 1995], we can design the following equation for VHi:

$$m_i \frac{d\vec{v}_i(t)}{dt} = m_i \frac{v_0\vec{e}_i - \vec{v}_i(t)}{\tau} + \sum_{j(j\neq i)} \vec{f}_{ij} + \mathrm{F}_{leader} \quad (7)$$

Where $\sum_{j(j\neq i)} \vec{f}_{ij}$ is force among virtual humans (we do not consider friction force).

4 An individual's Emotion Model

In the outside of the building, a virtual human can have two kinds of emotion, the first kind is fear, and the other is hope. We can suppose that emotion intensity is relative to the distance from the building, earthquake magnitude and other people emotion. We can construct the formula of fear emotion as the following:

$$e_{fear} = \max\left\{\cos^{\alpha}\left(\frac{d_{danger}}{D} * \frac{\pi}{2}\right), \sin^{\beta}\left(\frac{M}{M_{MAX}} * \frac{\pi}{2}\right), \sin^{\gamma}\left(a_1 * AVE_{fear} * \frac{\pi}{2}\right)\right\} \quad (8)$$

In the above formula:

D is the distance from the door to the safe area (in the middle of the ground), d_{danger} is the distance from the current position to the door. M is earthquake magnitude $M \in [1,9]$. α, β, γ are personality coefficients, for the C-type person, α, β, γ are equal to 1.0; For the N-type person, α, β, γ are equal to 0.5, they will enhance the fear intensity. For the O(E,A)-Type person, α, β, γ are equal to 2.0, they will reduce the fear intensity. AVE_{fear} is average intensity of fear emotion contagion from near around, a_1 is a regulation coefficient, $a_1 \in [0,1]$. $a_1 * AVE_{fear}$ is fear emotion contagion.

For the hope emotion, its intensity is relative to distance from current position to safe area and emotion contagion. We can construct the formula of hope emotion as the following:

$$e_{hope} = \max\left\{\cos^{\omega}\left(\frac{D - d_{danger}}{D} * \frac{\pi}{2}\right), \sin^{\theta}\left(a_2 * AVE_{hope} * \frac{\pi}{2}\right)\right\} \quad (9)$$

In the above formula, ω, θ are personality coefficients. for the C-type person, ω, θ are equal to 1.0; For the N-type person, ω, θ are equal to 2, they can reduce hope intensity; For the O(E,A)-Type person, ω, θ are equal to 0.5, they can enhance the hope intensity. AVE_{hope} is average intensity of hope emotion contagion from near around, a_2 is a regulation coefficient, $a_2 \in [0,1]$. $a_2 * AVE_{hope}$ is hope emotion contagion.

In the escaping process, the velocity of a virtual human can be calculated by the following formula:

$$v = V_{MAX} * \sin\left(\frac{P}{P_{MAX}} * \frac{\pi}{2}\right) * e_{fear} \quad (10)$$

In the above formula, V_{MAX} is the max speed, P_{MAX} is the max energy. Let P0 is initial energy and $V_{consume}$ is the speed of consumed energy, the current energy P is calculated by the following formula:

$$P = P_0 - \int_0^t (V_{consume}) dt \quad (11)$$

In the above formula, $V_{consume} = k_1 * v$, k_1 is coefficient of consumed energy, $k_1 \in (0,1)$.

5 Demo System

We design two 3D virtual scene and virtual humans to test the emotion model, the demo system was realized by Microsoft Direct3D and VISUAL C++, some of the demo pictures are in Figure 1-Figure 10.

In the first demo system, at the initial state, all the virtual humans stood in a hall. When they perceived the earthquake, the virtual humans began to escape. We selected three virtual humans in the crowd, they were named by Bob, Joan and Jack, and the corresponding personality type were C, O(E,A) and N in OCEAN theory. In the speed simulation for virtual humans, in order to compare the speed variations for different virtual humans, we suppose that all of them have the same speed in the exit.

In the example, let $\lambda = 5\text{X}10^3$ N, $r_i = 0.3$m, $m_i = 65$kg, $\boldsymbol{v}_i^0(t)$=3.0m/s. We construct $f(PS_i,)$ with following :

If $0.0 \leqq P_N < 0.5$, $f(P_N) = 1 + (P_N)^2$, if $0.5 \leqq P_N \leqq 1.0$. $f(P_N) = 1.25$.

For P_O, P_E, P_A, $f(P_O) = f(P_E) = f(P_A)$,

If $0.0 \leqq P_O < 0.5$, $f(P_O) = 1 + P_O^3$, if $0.5 \leqq P_O < 1$, $f(P_O) = 1.25$.

If $0.0 \leqq P_C < 0.5$, $f(P_C) = 1 - (P_C)^2$, if $0.5 \leqq P_C \leqq 1.0$, $f(P_C) = 0.75$.

In Figure 1, the crowd animation is realized by formula (7), emotion droved crowd panic, the crowd included some small groups. In Figure 2, the crowd animation is realized by Helbing's social force model, the crowd picture was different from the pictures in Figure 1. In Figure 3 and Figure 4, we use a virtual head to represent a virtual human emotion state. The facial animations are driven by blended technology, let GM_{fn} is a facial geometry, $fn \in [0, FN]$, FN is the number of different facial geometry, GM_0 is the geometry for neutral expression. Let wh_{fn} is a weight, $wh_{fn} \in [0, 1]$. In the paper, $wh_{fn}=\max(e_{fear} , e_{joy})$. In general, the geometry for new expression GM_{new} can be calculated by the formula:

$$GM_{new} = GM_0 + \sum_{fn=1}^{FN} wh_{fn} [GM_{fn}-GM_0] \quad (12)$$

In Figure 5, the unit of x-coordinate axis is time (frame number), the unit of y-coordinate axis is fear intensity. In the initial state, all the fear intensities are random values, inside the building, emotion contagion enhance one's fear intensity, in the exit, the fear intensity is near to 1(the max value for an emotion intensity). When a virtual human is outside of the building, the fear intensity will decrease with time, there is little emotion contagion, and result in a small rebounding in fear intensity variation.

In Figure 6, there was no hope emotion inside of the building, when a virtual human escaped outside the building, the hope intensity increased with time. In Figure 7 and Figure 8, in the escaping process outside the building, the speed and energy for a virtual human decreased with time.

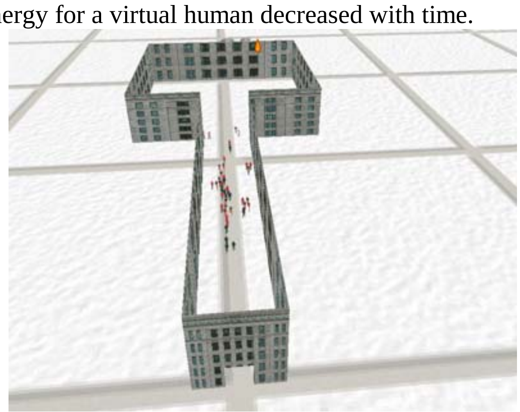

Figure 1. a crowd with the emotion model escaped to exit.

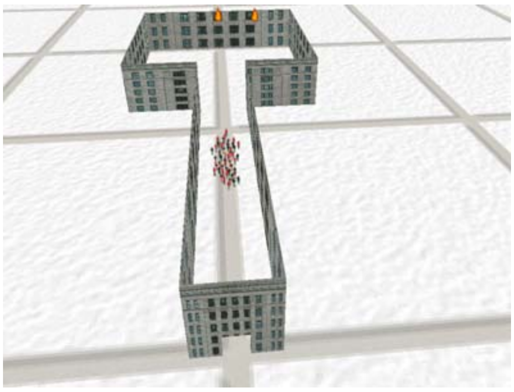

Figure 2. a crowd with the social force model escaped to exit.

Figure 3. a virtual human's fear facial expression (his personality is O(E,A) type).

Figure 4. a virtual human's hope facial expression (his personality is O(E,A) type).

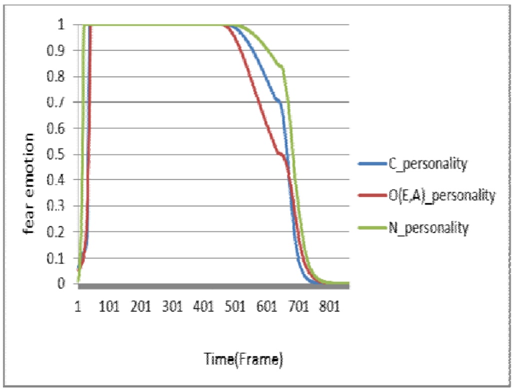

Figure 5. The variations of fear emotion intensities for the virtual human with different personality.

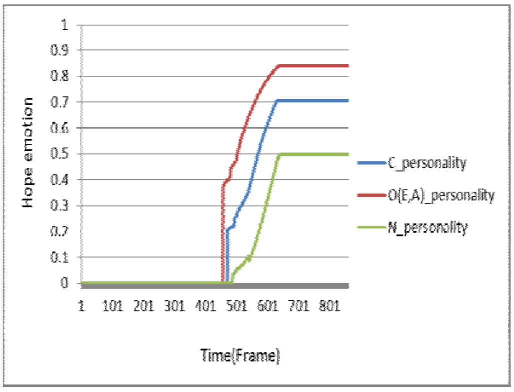

Figure 6. The variations of hope emotion intensities for the virtual human with different personality.

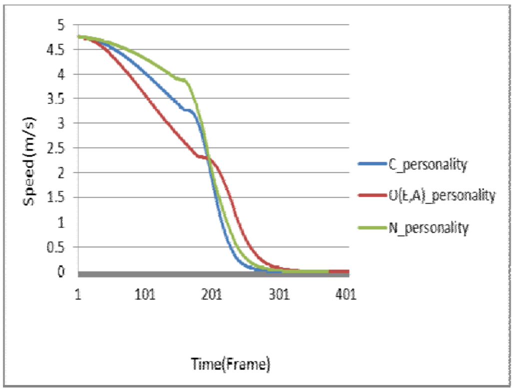

Figure 7. Speed variations for the virtual human with different personality (the initial state is in exit location, the simulation is for outside the building)

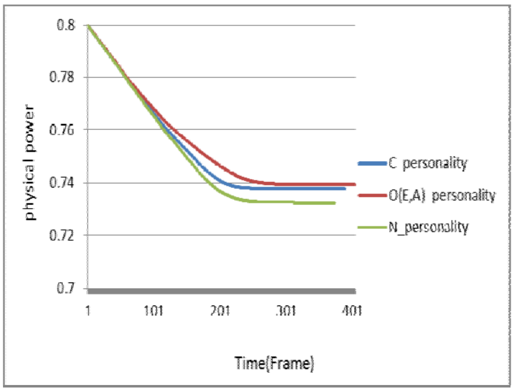

Figure 8. Physical power variations for the virtual human with different personality(the initial state is in exit location, the simulation is for outside the building)

In the seconde demo system, an emergent event based crowd escaping on a bridege is set up with the above model, we consider the emotion contagion, the demo pictures are in Figure 9 and Figure 10.

Figure 9. A crowd evacuation with no emotion contagion model on a bridge

Figure 10. A crowd evacuation with emotion contagion model on a bridge.

6 Conclusion

emotion simulation for virtual human is a meaningful topic in artifical intelligence, many accidents show that emotion contagion can increase crowd panic, the resarch on emotion model can help people to find methods to prevent trample. In the paper, we summarize the current researches on emotion model, and a computational emotion model is presented, the parameters of a virtual human are introduced, and some formulas are constructed by psychology theory. The model is illustrated with two escaping demo system. From the simulation, emotion contagion can enhance fear intensities of a virtual human. The effects of emotion contagion will decrease when a virtual human is outside of a building.

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