Emotional Contagion Driven of Parent-Child's Agents in Crowd during Panic Situation

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Summary
Crowd simulation has been studied extensively for the past two decades. The behaviour of a crowd or pedestrian somehow is determined by the inner emotion of each agent. Occasionally, the inner emotion has been influenced by surrounding atmospheres. Emotion along with Seek-flee are factors that important on simulating the crowd under the panic situation, whereas, the agent tries to seek a way out or other agents and some agents maybe try to flee because of scared or desperate. This paper proposes a unique solution for demonstrating the behaviour of emotional contagion model for parent-child agents inside the crowds. The finite state machine(FSM) consists of two main states for a regular and panic situation. The two scenarios have been introduced to demonstrate the wandering and seek-flees states. Wandering states will trigger an agent to walk toward a certain direction randomly or idle only. Whilst, the seek-flee behaviour demonstrate two parents looking for their child and once they meet each other, it will drive the crowding agent to stick together and flee. The parent-child's bond inside the crowd is a promising feature to be investigated further especially with a huge number of agents and multi-hazard situation.

Key words:
Emotional Contagion; Crowd; Finite State Machine; parent-child.

1. Introduction

The crowd behaviour has been widely used for simulation, movies or even for educational purpose. Since the technology also grew significantly over the past decades, the crowd algorithm is easily evolved as well. Previous research has focused on collision avoidance known as reciprocal velocity obstacles[1]. Its mainly consider the reactive response from other agents where the perceptive of collision avoidance used for navigation of the agent. Their approach can be implemented in both motionless and moving obstacles. The other researcher concentrated on building large crowd simulation with their unilateral incompressibility. It has been claimed that their work capable of producing large-scale crowd and its behaviour along with collision detection among the agent itself[2]. Their works have demonstrated high dense crowds with hundred thousand agents with only desktop computer.

This paper offers a novel approach towards crowd simulation with contagion emotional model between parents and child that may exist in the crowd during a panic situation. The parents naturally will seek for their child in case they are separate in the crowd and they will try to flee soon after they reunite with their kids. This paper consists of 5 sections: section one is the introduction of the proposed work, followed by section two that present research gaps in the related works. Section three focused on the methodology of the proposed approach and section four present the result and discussion toward the implementation. Finally, section five bring the conclusion of the whole manuscript as well as future works that can be carried out in further research.

2. Related Works

Narrain, A et al. demonstrate the dense crowd that consist of hundred thousand characters by introducing the Unilateral Incompressibility. They calculated the agent motion through grid velocity according to the position of agent ($v(x_i)$) known as agent i velocity. The agents also have their own desired velocity ($\tilde{v}$) approach. By considering the density of crowd at a certain location $r(x_i)$, then the velocity of agents can be computed through equation 1:

$$v_i = \tilde{v}_i + \frac{\rho(x_i)}{\rho_{\max}}(v(x_i) - \tilde{v}) \qquad (1)$$

Fig. 1 The large and dense crowd in the trade show[2]

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The formal state approach known as X-machines has been proposed to model the emergency situation of virtual agents[3]. It is dedicated for evacuation plan when an emergency situation has occurred. The model consists of an emotion model that might affect the agents during hazard state. The emotion model is presented to augment the realism of the simulation. Their demonstration using Netlogo and Prolog is successfully shown the behaviour of the crowd with emotion elements[3,4]. Xu, M. et al. have strengthened that emotion contagion during multi-hazard condition is important for simulating the realistic behaviour of human. Their Emotional Reciprocal Velocity Obstacle(ERVO) in an enhancement of Reciprocal Velocity Obstacle(RVO) model with emotional contagion. The impact of the emotional relationship between agents and collision avoidance is presented in their work[5]. Fig.2 shows the comparison model between crowd simulation with and without emotional contagion elements. Xu,M. et al. works in Fig.2 shows that agents with emotion have the capability to get away from the emergency spot even they are not following the trail. Whilst, the agents without emotion will stick to the given predefined path which is prepared for them. This means their work is capable to enhance the realism of crowd simulation by providing emotion in a hazard situation. Because in the real life the movements of agents fully depend on their emotions such as fear, shock, anger, sadness, etc.

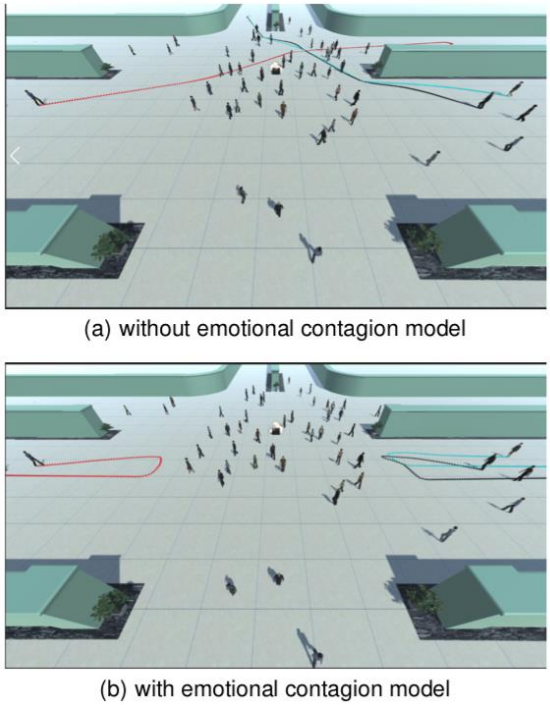


Fig. 2 a. Crowd movement without emotional contagion and b with emotional contagion[5]

The emotional contagion model also proposed by another researcher by bringing the real-life experience toward crowd simulation[6,7,8]. Fig .3 shows the behaviour of agents that generated based on the parameter that is taken from real life vide experience.

Fig. 3 [6] Generated scene based on real life experience[6]

The other researcher also focused on producing more behaviour toward the pedestrian by giving the agent ability to adapt toward the environment situation[9]. They produced two behaviours: following and group behaviour to avoid the obstacle or other agents. It also mentioned that their work mainly focused on group behaviour rather than an individual of each agent. Therefore, their work successfully demonstrates the behaviour of the agent with more perception, speed and lane establishment. Fig.4 shows the behaviour of two groups facing each other and moving toward opposite directions.

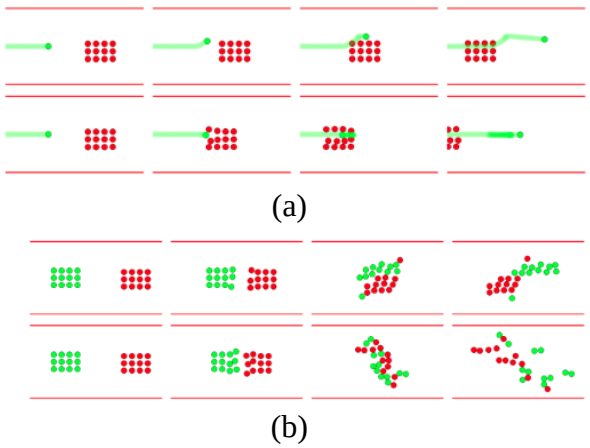


Fig. 4 a. An agent agains group , top with group avoidance method and bottom without group avoidance approach that make the agent went through the groups. b. group vs group , top with group avoidance, the group maintain their bond. While, bottom without group avoidance, the groups break up[9]

Abdullasim, N. et al. present the velocity perception that useful for collision handling. They consider the velocity to

predict the upcoming collision so it will reduce the computational cost of collision avoidance[10]. In addition, some researcher tried to improve the emotional behaviour of agents by adding an expressive character driven by emotional model or directly from the user through the brain-computer interface data set[11-13]. The emotion behaviour will lead to the decision making made by an agent during the interaction. The social contagion and copying behaviour will lead the agents to be closed as real human behaviour[14,15].

3. Methodology and Experiment

As mentioned in the previous chapter that our work will be focused on the special relationship (parent-child) between the crowd that mixed up with emotional contagion during the panic situation. We adopt the Finite State Machine(FSM) for handling the behaviour of the emotional contagion crowd between parent and child. The whole process is depicted in Fig.5.

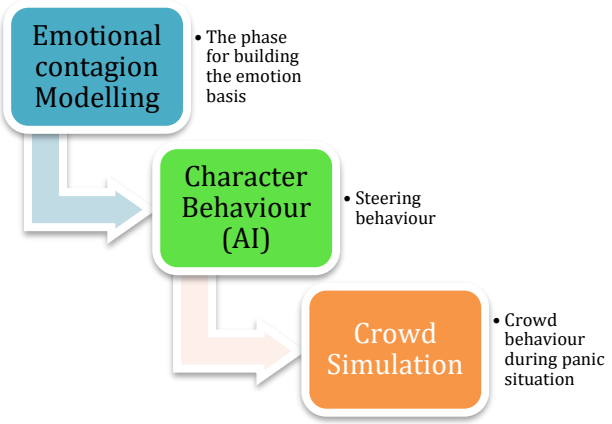


Fig. 5 Framework of emotional contagion crowd model

Fig. 5 show that the process is initiated by building the model of emotional contagion that will become the basis of character emotion followed by handling the steering behaviour of characters. Finally, the crowd simulation behaviour that consists of several simulations such as wandering, seek and flee, etc.

We adopt the emotional contagion model proposed by Xu, M. et al. that consider the strength of danger (within the range [0,1]) as a parameter to calculate the impact that perceived by agents during panic situation as stated in equation 2[5].

$$E_i^h(P,t) = \sum_{s=1}^{n} G_s(P,t) \qquad (2)$$

Where $E_i^h(P,t)$ embodied the panic rate of the agent(i) disturbed by each danger s at time t and Positions P, and n is the number of danger that happens to the agents. Based on the observation that the real-life cases have shown that each individual inside crowd is potential to carry terrify behaviour and even spread it toward another individual inside the crowd. The emotion contagion will start spreading to infect another individual that closed to them. The emotional perception among agents is different depending on the temperament of each agent. Therefore for the agent i that become a subject which is received all effect from agent j who is emotional within comprehend distance at time t, can be calculated with equation 3[5].

$$E_i^c(P,t) = \sum_{t'=t-k+1}^{t} \sum_{j=1}^{n} d_i(t') E_i^{c'}(P_j,t') \qquad (3)$$

Where $d_i(t') \sim N(0.1,0.0001)$ symbolized the amount that received by agent *i* from agent j at time t'. $E_i^{c'}(P_j,t')$ is the panic level of agent *j* within radius of agent *i* at time *t*. Since our proposed approach focused on the parent-child agent, therefore we did a modification of equation 3, resulted in equation 4:

$$E_i^c(P,t) = \sum_{t'=t-k+1}^{t} \sum_{j=1}^{2} d_i(t') E_i^{c'}(P_j,t') \qquad (4)$$

We assumed that some agents have 1 or two parents that will affect their behaviour during a panic situation. The agents will be affected by both or one of their parents during a panic situation and the kids also will try to find their parents.

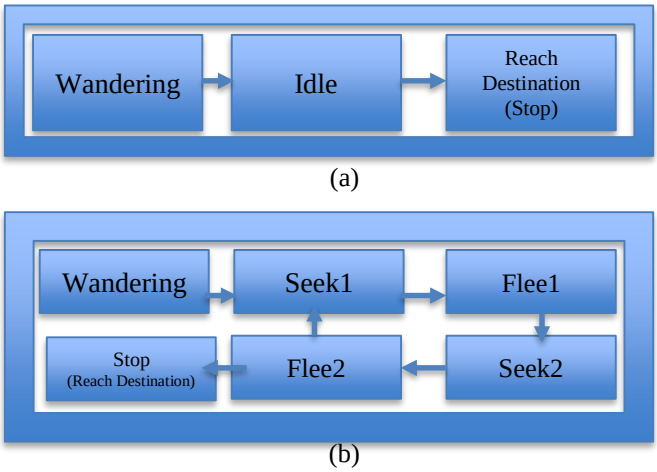


Fig. 6 FSM States of agent (a) during normal situation. (b) FSM states for agent in the panic situation

Fig.6 (a) shows two kinds of states that might occur toward the agent, the first state portrayed agents in a normal situation. They will have wandering, idle or reach destination. Whilst, Fig.6 (b), when the agent in wandering state then the panic situation has emerged, the agents (parent or child) will enter seek and flee states and loop until certain condition achieved (parents found their child's or the opposite) then it will stop. As mentioned before that the bond between parents-child's are so strong, therefore even the panic situation emerged the nature of parent-child will emerge and end up with seek-flee behaviour until they meet each other or reach the safe area.
The algorithm for wandering is initiated from the starting position with fixed starting point then randomly move to every direction as shown in Fig.7 and Fig.8.

Algorithm 1

```
Initiate
while not stop do
cast ray R;
Set random direction ϕ
do wandering
end
stop idle Mode;
```

Fig. 7 Algorithm for wandering state

Algorithm 2

```
Initiate
while not stop do
cast ray R;
Set destination D
do Seek
do Flee
end
stop idle Mode;
```

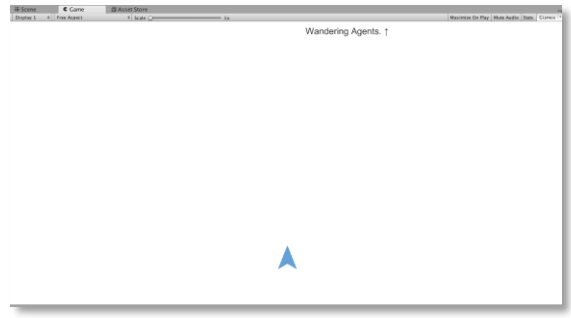
Fig. 8 Algorithm for Seek-flee state

4. Result and Discussion

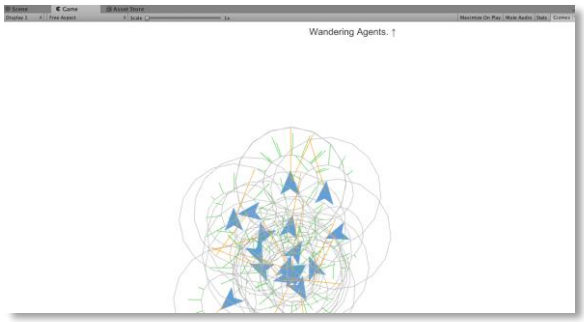
We have built the simulation based on Polarith AI and Unity3D [16,17] to show the behaviour of each agent during a panic situation. There are several scenarios that applied in the simulation, the first scenario is wandering during a normal situation. The agent will explore the environment by walking in every direction. The second scenario is Seek-flee that occurred when an emergency situation occurred. Then, when parents found their kids so they will escape the emergency scene immediately.

4.1 Scenario 1: Wandering (Regular Condition)

Its initiated by all agents grouped together in the same position.



(a)



(b)

Fig. 9 (a) Agent at initial position. (b) Agent start spreading for wandering

Fig.9a and 9b show the position of the gent during initial rendering, all agent start to moves to every random direction as wandering states is started. The agent will keep moving to any direction as shown in Fig.10.

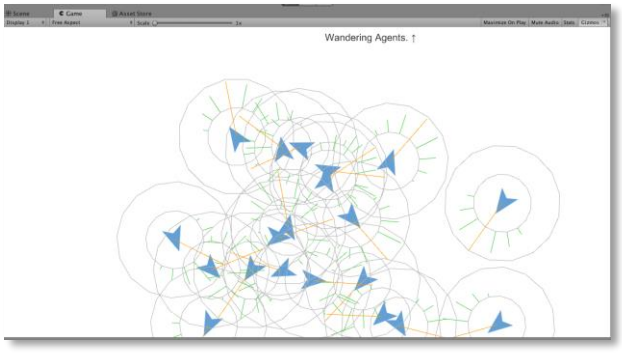
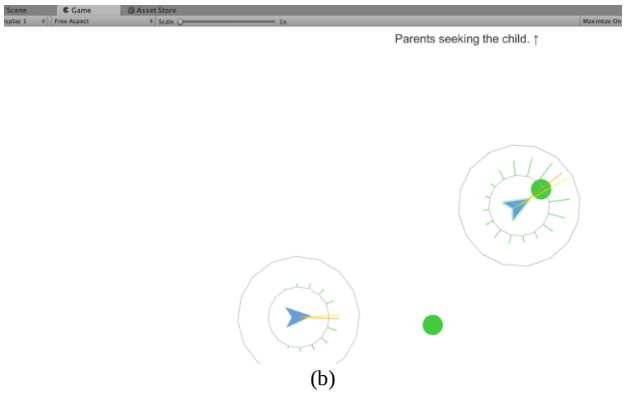


Fig. 10 Agent dispersed and move to any direction in wandering state

4.2 Scenario 2: Seek – Flee (Panic Situation)

The seek-flee scenario is core things that we proposed in this research. The parents will seek for their child's when it meets up it will go along with them to flee from the emergency scene. Fig.11a and 11b show there are two parents seek for their child. Firstly, they already decide their target within range then approach them, once they grouped together, the parents will hold their child together and they will flee immediately from the panic scene.

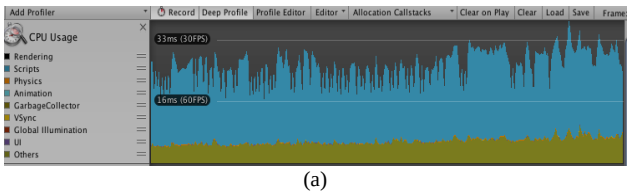
(a)



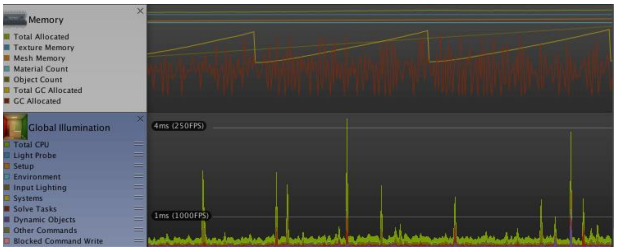
(b)

Fig. 11 Agent dispersed and move to any direction in wandering state

We have measured the FPS, CPU and memory usage during simulation as shown in Fig.12a and 12b.



(a)



(b)

Fig.12 a. CPU usage and b. memory consumption

Fig.12a illustrate the 30 FPS will require 33ms while sometimes the application can reach 60 FPS that will consume only 16ms processing time. As depicted from Fig.12b, the memory consumption will normal and not excessively took the whole memory that available at our rendering machine.

5 Conclusion

This research has proposed an innovative solution for crowd simulation with agents that have a strong bond such as parent-child relationship. The emotional contagion model is proposed to introduce the bond relationship between parent and children. It's found that during wandering states agents only move randomly without specific goals. While in the panic situation certain agents, in this case, parent-child agents will seek each other, when it's found it will be grouped together to flee into a safe area. This work still has a lot of room for future improvement because the special bond relationship is still less explored and challenging. The huge number of agents with special bond might be considered for future development with an intention to increase the realism of crowd simulation.

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