Is that How Everyone Really Feels? Emotional Contagion with Masking for Virtual Crowds

Tim Balint and Jan M. Allbeck

Laboratory for Games and Intelligent Agents
George Mason University, 4400 University Drive, MSN 4A5
Fairfax, VA 22030
`jbalint2,jallbeck@gmu.edu`

Abstract. Many simulations use emotional contagion to simulate how groups of humans behave in emotionally charged environments. These models either have each individual agent conform to a group emotion, or have emotional spirals. However, these models do not include well known phenomenon such as displaying and receiving emotions through different means of communication, or having emotions masked by an agent's desired display emotion. We create a model of emotional contagion that considers multiple channels to communicate on. We also provide a method for agents to mask their emotions, which is used to control the spread of contagion between agents, and can prevent emotional spirals. We demonstrate our model with a sample scenario, and show the effects of having multiple channels and emotional masking on the overall emotional contagion for several groups of agents.

Keywords: Group and Crowd Simulation;Personality and Emotion Models;Modeling and Animation Techniques;Applications in Games;

1 Introduction

Multi-agent simulations capture the interaction between groups of humans, and are used in applications such as games, movies, and civil design. These interactions attempt to model human behavior in varying situations, and include human characteristics such as emotion, which tend to be designed using either an appraisal system [1] or a valence system [2]. While these models attempt to explain how emotions arise individually, the propagation of emotions, known as emotional contagion, captures emotional interactions between groups of humans. Emotional contagion allows for group reactions to stimuli, even if not all members of that group receive the stimuli. For example, in a movie such as *Godzilla*, not all the people running away in fear have actually seen Godzilla. Some become afraid because they see others running away in fear. Having virtual agents with emotional contagion allows for scenes such as this to be more realistically rendered.

Hatfield et al. [3] has shown that contagion occurs through unconscious mimicking of other's emotional features, such as facial expressions. This is known as momentary micro mimicry, which transfers a small amount of emotion. This can be amplified when continuously being exposed to the stimuli or occurring within a large group, and can lead to phenomenon such as emotional spirals, where the emotional amplitude grows out of control. While Hatfield et al. primarily focused on facial expressions, they mentioned several other channels with which emotion can be interpreted and mirrored. For example, if someone is in a large, aggressive stance, another person could momentarily shift their stance, becoming angrier in the process. Most current contagion implementations use proximity or group cohesion to determine the spread of emotion, however, using multiple channels would allow for more realistic human simulations, as physical humans have varying abilities to encode and decode their emotions on these different channels.

Emotional contagion is also an unconscious effect, and it would be fool-hardy to believe that it is not always present in crowds. However, there are many situations in which emotional spirals do not occur and contagion is at a minimum. People commuting home from work on the train do not experience emotional spirals, even though they are all essentially of the same group, and confined together for long periods of time. This is most likely due to the commuters outwardly displaying little to no emotion, which is known as emotional masking. Furthermore, the sender may not wish to convey their emotions, and so will send more obvious signals to convey a different, or false emotion. Someone who is sad may take on a neutral pose and expression, so that they do not betray their emotions to others, while still considering their inward emotion when interpreting the environment. While there has been much research on having virtual agents displaying emotions [4], most have their *display* emotion be their outward emotion.

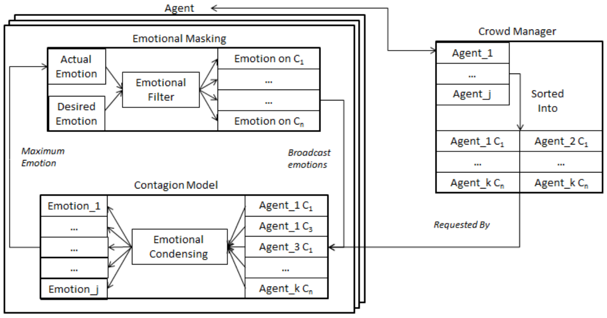


Fig. 1: A graphical representation of our system.

To create more realistic multi-agent systems, we have developed a novel model of emotional contagion that incorporates emotional masking, and provides agents several methods of communicating and receiving emotions, depicted in Figure 1. Our agents use this novel masking to determine a display emotion, broad-casted on several channels. A crowd manager determines which agents can receive these broadcasts and appropriately directs the information into each agent's contagion model. This information is then condensed into bins, with the highest becoming the new emotion for each agent.

2 Related Work

There have been several models of emotional contagion for crowds of agents. [5] have contagion as an emergent effect inside part of a larger crowd simulation engine. A couple of other models [6, 7], use only one emotion, fear, and are used to predict human movement in fearful situations. These models were later validated from panic situations in [8]. Various other models use a small set of emotions [9–11], and model the inter-connectivity between emotions. Many of these models use either proximity or interpersonal connection between agents when determining the spread of emotions. This generates group emotions, and keeps contagion among those group members. However, there is a large swatch of psychology literature that also shows contagion happens between strangers [12, Chapter 3], [13]. Our method captures this emotional spread by passing emotions through several simulated virtual channels between groups of agents based on channel visibility.

Emotions have also been used for several other applications including negotiation [14]. Additionally, it has been shown that physical humans can understand emotions from virtual agent's facial expressions [15], body posture [16], vocal patterns, and gestures [17]. If physical humans use these different channels to understand each other's emotions, virtual humans should be able to as well. In the context of emotional contagion, these factors are what humans use to mimic each other and are the mechanism for conveying emotions between agents. Also in recent years, there has been some work in understanding how humans decode emotions even if they are masked. Both [18] and [19] have examined if humans can recognize emotions when a neutral face is shown quickly after seeing an emotional face.

There have been many systems that provide agents with emotional contagion but none have incorporated the use of emotional masking to more naturally control the spread of emotions. Spreading emotions through multiple channels can be computationally complex, especially when the number of agents is large and dense. Our method accounts for these two complexities, to create a more realistic contagion system.

3 Emotions and Agents

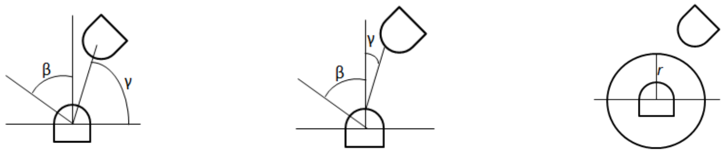
Emotional masking and contagion cannot take place in a group of agents if they lack an understanding of emotion. We adopt an approach, similar to [9, 11], using the emotional transition table developed by Adamatzky [13]; namely *happiness(H)*, *anger(A)*, *confusion(C)*, *sadness(S)*, which is referred to as *HACS* emotional states. We use Adamatzky's model because it simulates transistions between non-paired emotions, such as happiness and sadness. To represent low emotional states, we add a *neutral(N)* emotion for the agents to display. Emotions can be transitioned to from other states using the state transition diagram from Adamatzky and seen in Figure 2. Using the *HACS* model provides several advantages: that transitions occur in discrete event probabilities and that emotional coupling of a shared emotion does not change states, which can preserve emotional spirals.

Sending Receiving	**H**	**A**	**C**	**S**	**N**
H	H	C	C	C	N
A	C	A	A	A	N
C	A	C	C	C	N
S	A	S	S	S	N
N	H	A	C	S	N

Fig. 2: The transition diagram between agents using *HACS*. In this table, the transition is the most probable contagion response for an agent with their given emotion encountering another agent with a given emotion.

3.1 Emotional Contagion

Our system creates an emotional contagion model that operates on the *HACS* model of emotion. Using our model allows agents to spread and communicate their emotional state, using environmental variables that surpass mere proximity, and, with the correct necessary conditions, creating emergent effects like emotional spirals.



(a) (b) (c)

Fig. 3: Different methods of computing agent channels between two agents, with perception occurring from the center agent. (a)Computing non-reflexive channels using Equation 1, where β is half the field of view, and γ is the angle between agents. (b)Computing reflexive channels using Equation 1, where β is half the field of view, and γ is the angle between the agent's center of field of view. (c)Computing non-reflexive vocal channels using Equation 2.

The first step in our emotional contagion model determines the subset of agents and channels that an agent can perceive emotions from, and is performed by the crowd manager section of our model from Figure 1, and is similar to [20] in that we process which channels can be observed in a crowd management system. To determine a valid connection, a boolean function F_c, based on sensory perceptions like those found in [21]. Several of these perception channels are reflexive, in that if F_c is true for one agent, it is for both agents, and does not need to be repeated. We have three primary methods for determining channels. Specifically, we use non-reflexive equations for body posture and gestures seen in Figure 3a, reflexive functions for facial expressions and gaze seen in Figure 3b, and, vocal features based on Figure 3c. Using these equations, a crowd manager can construct a graph of all the channels each agent can perceive every other agent on, which, for large groups of agents, can become sparse. It can also be observed that, for large, dense areas, an agent should not be expected to momentarily mimic all other agents instantaneously. If a given agent is inside a crowd, the momentary micro mimicry should occur sequentially or between a small number of agents at a time. Using a sparse graph representation allows the agent to examine a small number of agents at a time, without having to section off agents or recompute calculations at every frame.

$$F_c = -\beta < \gamma < \beta \tag{1}$$

$$F_c = dist(agents) < r \tag{2}$$

The data from this sparse graph contains a list of emotions and channels, and each agent can request the list built for them from the crowd manager. By using a crowd manager to maintain the sparse graph, the number of computations are decreased by the number of reflexive channels. The received emotions from the list are processed by our emotional contagion engine, by determining the strength of the received emotion on channel i, e_{ci}, and weighing it with w_c, the agent's ability to decode emotions from channel c, as seen in Equation 3. It should be noted that w_c can either be assigned by a simulation author, or created using psychological properties such as those found in [22]. Then each e_{rc} are probabilistically placed into a bin $received_i$, based on the type of received emotion and Figure 2. Our probabilistic system will either place the emotion to the bin of the emotion received or the transition bin, with a higher probability of being placed in the transition bin. For example, if an agent is experiencing *happiness*, and attempts to decode an agent displaying *sadness*, then the happy agent has a likely chance to become confused, but may also become sad from it.

$$e_{rc} = e_{ci} * w_c \tag{3}$$

Once an agent probabilistically condenses all channels into $received_i$, it is added back into the agents emotion, as seen in Equation 4. A summation of all the perceived emotions is performed, which is then subtracted from each value of *received*. If most of the perceived emotions are neutral, this has the effect of lessening any perceived emotional contagion. We control the influence this summation has with a constant α, which controls the speed at which emotional spirals happen for single emotion simulations. Setting α greater then 1 keeps the system from always culminating in an emotional spiral.

$$e_i = received_i - \frac{\alpha * \sum_{i=0}^{n} e_i}{n} \tag{4}$$

3.2 Emotional Masking

Most physical humans do not display their true emotional state all of the time. It can be inappropriate or unwise for a person to express their feelings in certain situations. Emotional masking attempts to hide the emotion being felt by a person through the display of another emotion, or by not displaying any emotion. An agent may decide to mask their emotion, or be told to by a simulation author, allowing an agent to have a *true* emotion used for other processes, such as decision making, and a *display* emotion that can be received by other agents. It has also been shown that the effectiveness of masking one emotion with another is emotion dependent [18].

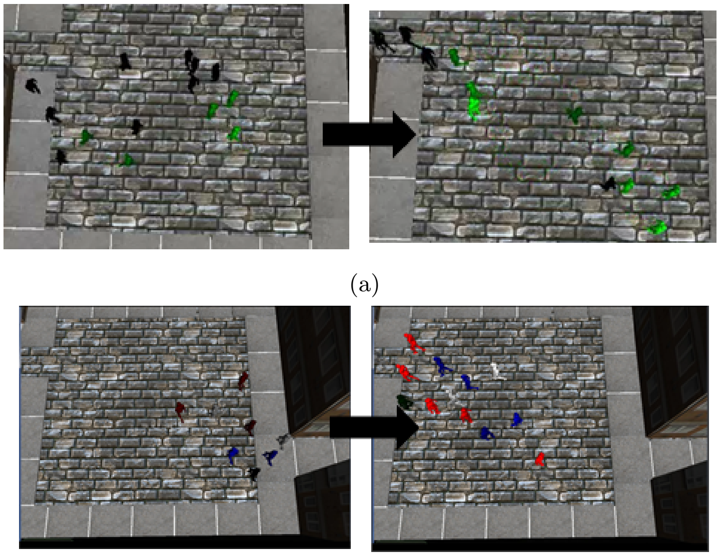
To determine the type and intensity of the emotion displayed by an agent, we combine the actual and display emotion with an emotional filter, using Equation 5. This equation uses the true emotional intensity e_i, the desired display emotional intensity e_j, and a weight w_{ij} that represents how effective masking one emotion with another is, based on Rohr et al. [19], which determined that physical humans can easily mask anger, sadness, and confusion with one another, but cannot easily mask happiness. The agent then determines if the displayed emotion e_{dis} is positive, and if so, the agent can successfully mask their emotion using their desired display emotion. e_{dis} is then treated in the same manner as the true emotional intensity was in Section 3.1.

$$e_{dis} = e_i - w_{ij} * \frac{e_j}{1 + e_i} \tag{5}$$

4 Experimentation

We examine the effects of emotional masking and using separate channels by implementing our model in a virtual agent system. Control of our agent's walking and gesture realization is provided by Smartbody [23]. All agent's channel weights are normally distributed. The intensity of each agent's displayed emotion is shown as the agent's primary color, with black representing no emotion and green, red, blue, and grey respectively representing an emotion from $HACS$.

We simulate a group of agents walking down the street on a normal day, much like commuters going home in the evening. Several agents are walking pass each other, all of which have been given various intensities of all five emotions between zero and half of the maximum intensity. Figure 4 shows the use of masking for agent contagion when simulating agents acting as commuters.



(a)

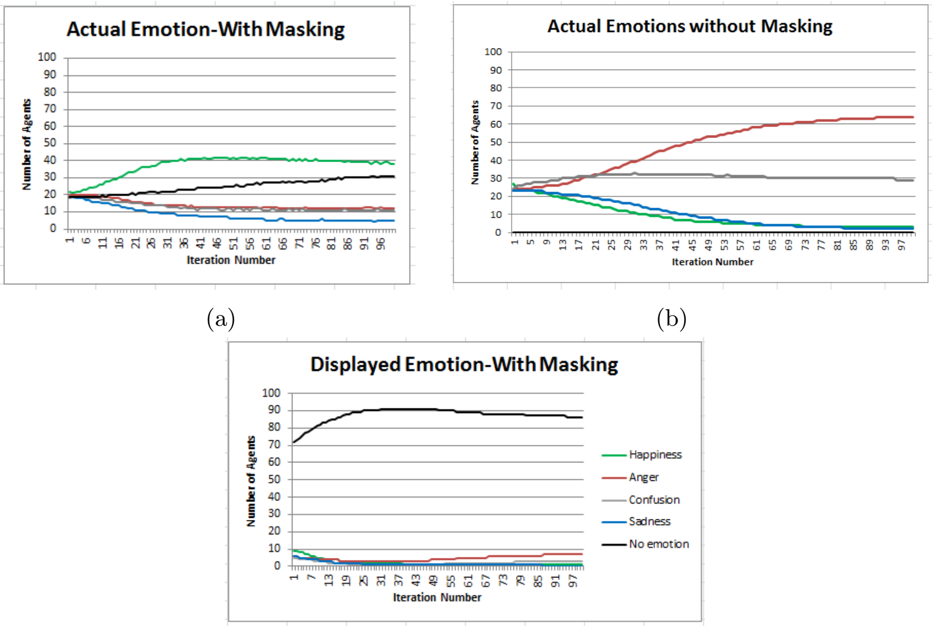
(b)

Fig. 4: A sample scenario of several agents walking through an environment. (a)Agents are masking their emotion with a neutral emotion. (b)Agents are not masking their emotions at all, resulting in an unnatural spread of emotions.

From Figure 4a, when agents mask their emotions with neutral emotions, the overall intensity of a displayed emotion is much less, as is the amount of contagion. This is to be expected, as agents that are hiding their emotion should not be passing their emotion onto others. When masking is taken away, the agents conform to a few emotions with much higher intensities. Specifically, many of the agents are either angry or confused. When examining Figure 2, this is to be expected. Most of the transitions in the table are either towards angry or confused, and these transitions are stable when angry agents perceive confused agents. Therefore, when these agents encounter each other, and decode each other's emotions we expect agents to display a high intensity when not masking. Combining contagion with masking gives a more realistic everyday scenario for physical humans, where most do not display emotion, and therefore, do not create these emotional spirals in crowds. This means our system allows a scenario author the flexibility to alter parameter settings and achieve the likelihood of emotional contagion they desire while maintaining plausible agent behaviors.

We also examine how emotional masking affects the total number of agents that outwardly display emotions, for both masked and open settings. Channel weights for each agent are determined from a uniform distribution, as are the type and strength of each agent's starting true emotion. Each agent is constrained to a fixed grid, and at the end of each iteration, may move one space over on that grid, or slightly change their orientation. This reduces the number of agents that form closed groups. When masking emotions, the agents use a neutral state, with an intensity between ten percent and half of the emotions maximum intensity. The results of fifty runs at 100 iterations is seen in Figure 5.

From Figure 5c it can be seen that with masking, the number of agents that display no emotion is much greater than any other set of emotions. This does not mean that emotional contagion is not occurring, as can be seem from Figure 5a. This shows contagion still occurs, as the number of happy agents rises as time goes on. This occurrence is much slower then without masking, seem in Figure 5b.



(a) (b)

(c)

Fig. 5: The number of agents vs. the iteration number for multiple emotions. (a)The number of agents actually feeling each emotion when masking is enabled. (b)The number of agents displaying each emotion without masking. (c)The number of agents displaying each emotion when masking is enabled.

5 Conclusions

We present a model of emotional contagion that allows an agent to decode emotions on multiple channels. In order to do this, we created a system to encode and decode emotions on several channels, using a probabilistic transition between different types of emotions. To allow for downward emotional spiral and neutral scenes, we implemented a method for emotional masking that allows an agent to determine which emotion they wish to display, and mask their felt emotions, allowing for an over-abundance of neutral expression. A neutral expression causing a downward spiral is similar to the military coming to fight Godzilla, calming the populous with their stern emotional neutrality.

While our system adds several human characteristics to a contagion model, it also has several unrealistic limitations. Agents in our system display the same emotion on all channels, and these are always correctly interpreted by the surrounding agents. In realistic situations, this is not always the case and an interesting addition would be to examine mis-understandings of emotions. Also, our work is focused on having a contagion system where agents consciously control the display of their emotions, which we assume a group of agents would want to do. This is not always culturally realistic, and an interesting extension of this work would capture the influence of culture with this contagion system.

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