A Generic Emotional Contagion Computational Model

Gonçalo Pereira, Joana Dimas, Rui Prada, Pedro A. Santos, and Ana Paiva

INESC-ID and Instituto Superior Técnico and Universidade Técnica de Lisboa
Porto Salvo, Portugal
{goncalo.pereira,joana.dimas,rui.prada}@gaips.inesc-id.pt,
pasantos@math.ist.utl.pt, ana.paiva@inesc-id.pt

Abstract. This work describes a computational model designed for emotional contagion simulation in societies of agents, integrating the influence of interpersonal relationships and personality. It models the fundamental differences in individual susceptibilities to contagion based on the psychology study of Emotional Contagion Scale. The contagion process can also be biased by inter-individual relationships depending on the intimacy and power difference aspects of relationships between agents. Individuals' expressiveness in a group is influenced by both the extroversion personality trait and power difference.

Additionally, the computational model includes the process of mood decay, as usually observed in people, expanding its application domain beyond that of pure simulation, like games. In this paper we present simulation results that verify the basic emotional contagion behaviors. The possibility of more complex contagion dynamics depending on agent group relationships is also presented.

Keywords: emotional contagion, agents, personality, relationship.

1 Introduction

Throughout history emotions have been the focus of much interest, thought and research by many thinkers like Aristotle, Charles Darwin, Sigmund Freud and Walter Hess [15]. In computer science emotions have been researched for several decades, but their relevance was only widely projected by the seminal work of Picard[17]. The understanding and integration of affect in computer applications led to developments in areas such as videogames[20] and robot companions[4].

A scarcely explored and important process in agent believable simulations is Emotional Contagion (EC). It can be described as "the process through which we 'catch' other people's emotions" [10]. It is especially important in group situations where emotional states of individuals influence the behavior of others. Several examples of research inspired in processes of EC can be found in areas like Group Decision [14], Ambient Agents [3] and Interface Agents [16]. Further research into EC may have an important impact in several areas where believability of group behavior is important, such as games.

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The goal of our work is to improve an existing computational model of EC by integrating the influence of interpersonal relationships and personality as found in social psychology literature. In the following section we review some previous work, next we present our EC model, followed by some tests based on our implementation, conclusions and future work.

2 Background

2.1 Emotional Contagion (EC)

Emotional processes such as EC deal with the concepts of emotion and mood. Both are used to describe how people feel, but are in fact different affective states regarding both duration and intensity. While emotions refer to emotional experiences that last from seconds to hours, moods can last from hours to weeks. Regarding intensity, moods are generally less intense. [15]

EC has been researched from different perspectives and there are many definitions [10]. However, one of the most insightful works [9] defined EC as:

> *"the tendency to automatically mimic and synchronize expressions, vocalizations, postures, and movements with those of another person's and, consequently, to converge emotionally."*

This definition is supported by two basic mechanisms:

Emotional mimicry/synchrony
A process by which "people automatically and continuously mimic and synchronize their movements with the facial expressions, voices, postures, movements, and instrumental behaviors of other people." [8]

Emotional experience / facial, vocal & postural feedback
Following the previous mechanism, "subjective emotional experience is affected, moment to moment, by the activation of feedback from facial, vocal, postural, and movement mimicry." [8]

These mechanisms are mostly primitive in the sense that they are automatically or unconsciously controlled. An example of the process is when a "source" person tells a friend about a happy event. The friend automatically synchronizes some of his own expressions by the mechanism of mimicry. The feedback mechanism is then activated and he experiences happiness as the "source" person felt.

The EC process is especially important in group dynamics and its effects have been presented in significant research. One in particular [1] shows the influence of EC at both the individual and group level on increased perceived task performance, increased cooperativeness and decreased conflict. Another effect of EC is emotion amplification (or "Emotion Contagion Spirals" [3] or "upward/downward spirals" [7,6]), based on a single emotional expression, other group members can be infected with the expressed emotion and also start expressing it. This creates an amplification of the initially expressed emotion in the complete group. Notice that this effect can be both a positive or a negative influence on the group and its goals [18].

2.2 Emotional Contagion Biases

Different individuals have different susceptibilities regarding the contagion of emotions. Understanding the existence of such differences, Doherty [5] created and validated the "Emotional Contagion Scale". It is a fifteen unidimensional scale that measures an individual's susceptibility to others regarding five basic emotions: love, happiness, fear, anger and sadness. This scale makes it possible to quantify an individual's tendency to be influenced by any expression of the five basic emotions into a set of five discrete values (one for the susceptibility to each emotion) each ranging from one (never susceptible) to four (always susceptible).

Beyond the individual inherent susceptibility, external factors such as interpersonal relationships, influence the contagion process. Kimura *et al.* [13] studied the effects of intimacy and power difference. In this work more intimate individuals showed greater contagion. In a relationship with a power difference between individuals, the one with more power was more susceptible to contagion. Identical results regarding the influence of power on EC had been previously obtained by Hsee *et al.* [11]. However, an older work by Snodgrass *et al.*[19] showed that subordinates were "more sensitive to the feelings" of their leaders. Our work follows the most recent research that indicates leaders as more susceptible.

Another EC influencing property is the expressiveness of individuals, which several factors can influence. Following previous work of Snodgrass *et al.*[19] on the susceptibility influence of power, it is indicates that one of the possible causes for the previous results is a greater expressiveness of the superiors, which in this case suggests superiors are usually more expressive. Another influence is that of personality which has been suggested, and only briefly investigated by Doherty [5]. Furthermore, Buck linked greater emotion transmission accuracy between individuals to extroversion.

3 Related Work

One of the few EC computational models developed was proposed by Bosse *et al.* [3] with the goal to simulate the occurrence of contagion spirals of negative emotions in ambient agents for virtual meeting support. Their "Emotion Contagion Spiral Model" is based on the characterization of a dyadic relationship. From the side of the emotion sender it is defined by its emotion level and its expressivity. On the receiver's side it is characterized by its emotion level and sensitivity to the sender. The strength of the communication channel between the two amplifies or reduces the communicated emotion. However, this work only models one emotion which is unrepresentative of humans where different emotions or combinations of them have different effects on people [15]. Additionally it does not enable the mapping of real data into agents and has a continuous simulation environment with an inevitable reach of equilibrium.

A different computational model of EC based on the EC scale (ECS) was proposed by Bispo *et al.* [2]. It models the mood of an individual (agent) which can be affected by emotional expressions from others. An individual is characterized by a "Current Mood" with values for five basic emotions (from ECS), an "emotional status" representing the individual's dispositional emotion and an "ECS Score" which determines its susceptibility. With this model the authors are able to simulate some EC patterns. However, the model continuously stimulates the agent, dismissing a mood decay as observed in humans and even implemented in agents. In the absence of another agent's expression the emotional status is used as a new emotional stimulus [12]. Furthermore, influences such as personality and interpersonal relationships are left out.

The existing computational models presented have several shortcomings. One is mostly focused on the collective emotional level rather than accurately reproducing the different emotions and their relationship with EC. Also, the second model despite having addressed a wider range of emotions, does not consider interpersonal influences on the contagion process or a decay of the mood status in individuals instead of a continuous stimulation process.

4 A Model for Emotional Contagion

Our computational model for EC builds upon the work of Bispo *et al.* [2] its conceptual map is presented in Figure 1. We maintain the central role of the EC scale and also acknowledge the EC effects at the level of mood contagion[1]. In our approach, we model the EC process at the individual agent level and group EC behaviors emerge from the interactions between agents. An agent can capture an "Emotional Expression" (EE) from the environment and filter it in the "Contagion Filter" to create a "Received Emotion"(RE) that is used to update its "Current Mood"(CM) by the "Mood Updater". When given a chance to express the agent decides on it with its "Emotional Expression Filter" and uses its "Current Emotion" (CE) to create a new EE.

An EE is used by an agent to interact with others in the same environment and is the basis of the model's dynamics. It is represented by the tuple $\langle t, i, o\rangle$. Element t specifies a type of emotion and can be one of the five emotions our model uses (inspired in ECS [5]): Love, Happiness, Sadness, Fear, Anger. While i represents the intensity of the associated emotion and is a positive real value, o identifies the transmitter of the expression.

4.1 Contagion Filter

In the "Contagion Filter" we transform an EE captured by the agent into a RE using two kinds of perception biases: susceptibility and contagion. The "Susceptibility Bias" probabilistically determines, based on the agent's individual ECS score and the type of the EE, if the agent is intrinsically affected or not. Each agent has its own ECS score for each emotion type given by the probabilistic function $ECS(t)$, where t is an emotion type. The susceptibility process is represented in Figure 1 by function $Suscept(t)$ (t is emotion type). It calculates a random value between 0 and 1 (with function $rnd(1)$ based on an uniform probability distribution) and compares it with the value of $ECS(t)$ for the received emotion type. Contagion occurs if $rnd(1) < ECS(t)$.

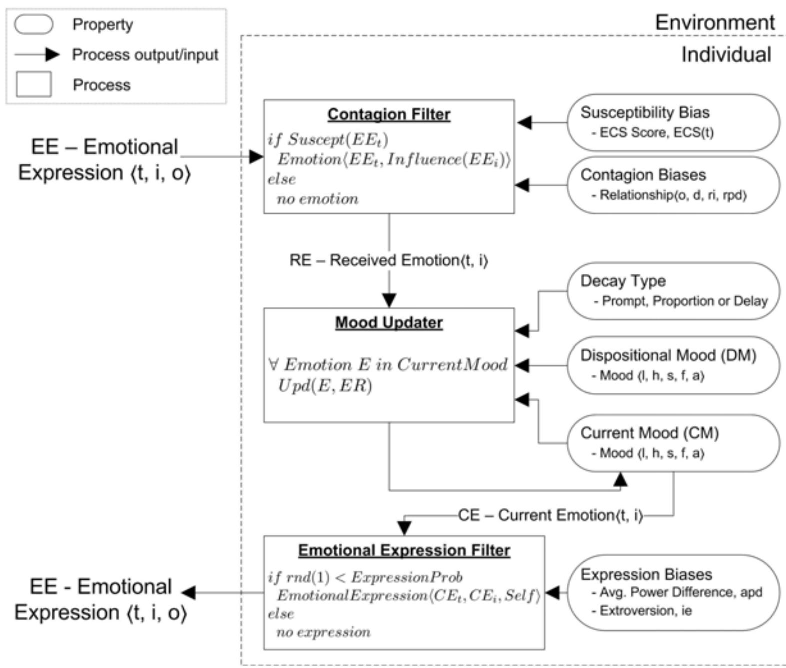

Fig. 1. Improved EC model diagram

Next are the "Contagion Biases" which determine how an expression received is influenced in terms of intensity, as some biases can make the perception more or less intense. The ones included are two relationship characteristics: intimacy[13] and power difference[13,11]. In our model we describe a relationship with the tuple $\langle o, d, ri, rpd\rangle$ where o and d map the origin and target of the relationship. Element ri represents the relationship intimacy property and ranges from 0 (not intimate) to 1 (very intimate). Element rpd represents the power difference characteristic and its value ranges from -1 (the agent is inferior) to 1 (the agent is superior). The influence these properties have on a received EE intensity is given by Equation (1). Intimacy has no effect if $ri = 0$ and a positive effect otherwise. Power difference has a negative effect for $rpd < 0$, no effect when $rpd = 0$ and a positive one for $rpd > 0$. Both properties have their maximum influence controlled by a percentage of the received intensity configured in the parameters i_range for intimacy and p_range for power difference.

$$Influence(EE_i) = EE_i(1 + ri * i\_range + rpd * p\_range) \tag{1}$$

As a result from the "Contagion Filter" a "Received Emotion" RE can be created. In our model an emotion is represented by the tuple $\langle t, i\rangle$ where t represents its type and i its intensity. If $Suscept(EE_t) = true$ the RE has the values $\langle EE_t, Influence(EE_i)\rangle$ otherwise no emotion is created. It is important to notice that emotions have a fixed maximum intensity.

4.2 Mood Updater

The agent's "Mood Updater" process uses the RE, CM, "Dispositional Mood" (DM) and a decay type to update the CM as given by Equation (2). In our model a mood is represented by the tuple $\langle l, h, s, f, a\rangle$ where l, h, s, f and a are represented by an emotion tuple. The CM represents the agent's current emotional status and the DM its dispositional one. An agent tends to its DM emotional status when unstimulated emotionally (no RE received).

If a RE is effectively received then the emotion in CM with a type corresponding to RE_t has its intensity updated by adding RE_i, emulating the emotional experience mechanism from EC. All the CM emotions, unaffected by RE, suffer a change in their intensity emulating an emotional decay. This change is formalized in the $Decay$ function which interpolates between the intensity of the emotion in the CM and that of the same emotion type in DM. Our $Decay$ function includes three types of decay: prompt (exponential), proportion (linear) or delay (logarithmic). These follow previous work[12] and let our system emulate different emotion decay patterns. An agent only uses one type for its decay.

$$\forall\ Emotion\ E\ in\ Mood\langle l, h, s, f, a\rangle$$
$$Upd(E, RE) = \begin{cases} E_i = E_i + RE_i, & \text{if } E_t \equiv RE_t \\ E_i = Decay(E_i, DM), & \text{otherwise} \end{cases} \quad (2)$$

4.3 Emotional Expression Filter

Finally, when an agent is given a chance to express himself emotionally, the "Emotional Expression Filter" based on "Expression Biases" decides probabilistically if it will express himself. If it does, it is based on the agent's CM. The expression biases considered are the power position of the agent in the group and its personality. These two biases are combined into a single probability value to decide on the expression as given by the Equation (4). The power difference influence is based on previous work [19] where an individual with a higher social power is more expressive. This is calculated by the Equation (3) as the average power difference (apd) from the N relationships the agent, representing its group power position.

$$apd = (\sum_{i=1}^{N} Ri_{rpd})/N \quad (3)$$

Regarding personality we only model the extroversion (ie) dimension, as it is the trait that influences the emotional expression the most. The higher the extroversion value the more expressive the agent is, a value of 0 makes it inexpressive and 1 the most expressive. The e_range parameter controls the maximum influence that apd can have in expression decision.

$$BiasedExpression = ie + apd * (1 - ie) * e\_range$$
$$ExpressionProb = \begin{cases} BiasedExpression, & \text{if } BiasedExpression \geq 0 \\ 0, & \text{if } BiasedExpression < 0 \end{cases} \quad (4)$$

As a result from the "Emotional Expression Filter" the agent creates an EE based on its CE for the other agents to capture. The CE is the highest valued emotion in the CM. The new EE is created with the values $\langle CE_t, CE_i * exp\_range, Self\rangle$, where exp_range represents the individual's expressiveness.

5 Model Simulations

In order to apply our model to different domains we must first verify the emergence of the basic EC behaviors added with our model (see the considered biases 2.2). To do so, we created a control scenario which predominantly creates an emotional spiral and compared it to the spiraling pattern of other scenarios (each exhibiting a different behavior). Each scenario was composed of a group of five agents to emulate a small group (similar to a RPG player's group that has several NPC companions). All agents had some common configurations: an ECS score of 2,75 (agents' susceptibility closer to "often" than "rarely"[5]), a prompt decay type(step of 0,3 due to discreet simulation), 0 intensity for all the emotions of CM and DM, a maximum emotion of 1000 (there is no fixed scale for emotion), an $e\_range = i\_range = p\_range$ of 0,5 and an exp_range of 0,2.

The simulation scenarios created were the following:

Control (Sc) all relationships have $ri = 0$ and $rpd = 0$. Agents with $ie = 0,5$;
Intimacy (Si) all relationships have $ri = 1$ and $rpd = 0$. Agents with $ie = 0,5$;
Power Difference (Spd) one agent is superior to all others having relationships of $ri = 0$ and $rpd = 1$ with them. The other agents have relationships with $ri = 0$ and $rpd = 0$. Agents with $ie = 0,5$;
Personality Low (Spl) all relationships have $ri = 0$ and $rpd = 0$. Agents with $ie = 0$;
Personality High (Sph) all relationships have $ri = 0$ and $rpd = 0$. Agents with $ie = 1$;

Each scenario was simulated 40 times and all the simulations had an identical predefined sequence. It started with an agent receiving an initial intensity of 50 (5% of the maximum emotion) for one of its CM emotions and then the agents would simulate the process of emotional expression/contagion for 100 turns. In each turn a single agent would be given the chance to express its current emotion for the group of agents, and if it did, the others who had been influenced would have the chance to express themselves in response.

The metrics used to evaluate the spiraling patterns of our simulations were:

Turn Maximum (TM) average turn time to reach maximum emotion;
Failed Spiral (FES) number of simulations which failed to create a spiral;
Average Contagion (AC) the average contagion value (RE_i) among all agents of the simulation;
Total Contagion (TC) the sum of all the contagion values (RE_i) that happened during the simulation;

Table 1. Simulation results and its standard deviations

	TM	σ	AC	σ	TC	σ	AEC	σ	AER	σ	FES
Sc	53,7	16,5	91,7	46,2	5033	2854	21,9	4,4	0,503	0,076	6
Si	37,2	14,6	206,4	33,7	11112	3873	22,0	5,1	0,504	0,083	0
Spd	66,4	17,8	54,8	43,2	2997	2548	21,1	6,2	0,497	0,144	10
Spl	-	-	-	-	-	-	-	-	-	-	40
Sph	15,5	2,1	175,9	3,3	27274	1736	66,7	4,5	1,000	0,000	0

Average Expression Count (AEC**)** the average number of times an agent generated an EE;

Average Expression Ratio (AER**)** the average ratio of AEC divided by the expressing chances.

The results of our simulations are shown in Table 1. When comparing scenarios *Si* and *Sc* we verify the expected (see 2.2) higher emotion contagion between individuals due to the agents' high intimacy relationships. This is shown by a quicker reach to maximum emotion (37,2 compared to 53,7) and much higher values for both average contagion (206,4 compared to 91,7) and total contagion (11112 compared to 5033). Intimacy reduces failed emotional spirals to zero since agents have increased emotion contagion between them.

Regarding *Spd* we can verify that the expected behavior of a single leader agent is more susceptible to contagion and more expressive with four other agents exhibiting the opposite behaviors. Due to a ratio of four subordinates to one leader we expected less emotional contagion, less emotional expressions and a slower spiraling effect. Regarding emotion contagion we indeed verified it, in both average contagion (54,8 compared to 91,7) and total contagion (2997 compared to 5033). The average expression ratio also decreased slightly (0,497 compared to 0,503) and a slower reach to maximum emotion (66,4 compared to 53,7) confirms a slow spiral. This scenario's symmetries are shown on high standard deviations for average contagion 54,8 $\sigma = 43,2$, total contagion 2997 $\sigma = 2548$ and average expression ratio 0,497 $\sigma = 0,144$. These symmetries destabilize the scenario regarding failed emotional spirals (10 compared to 6).

In the scenarios where we test the personality influence, we have a direct result for *Spl*. The very low value of extroversion does not enable any emotional spiral to emerge since individuals do not express enough to create one and agents quickly decay to their dispositional mood. Regarding the *Sph* scenario we observe that the highest extroversion (confirmed in the highest AEC=66,7) can have an even greater spiral amplification effect than intimacy. It is the quickest scenario to reach maximum emotion (15,5 compared to 53,7 in *Sc* and 37,2 in *Si*) and the one with the highest value of total contagion (27274).

Beyond the simulations done for patterns of basic behavior demonstration, the model can create more complex EC based dynamics. Such an example is shown in Figure 2 where a scenario with three agents (in order to make it visually simpler) was created. This simulation has a similar parameterization as

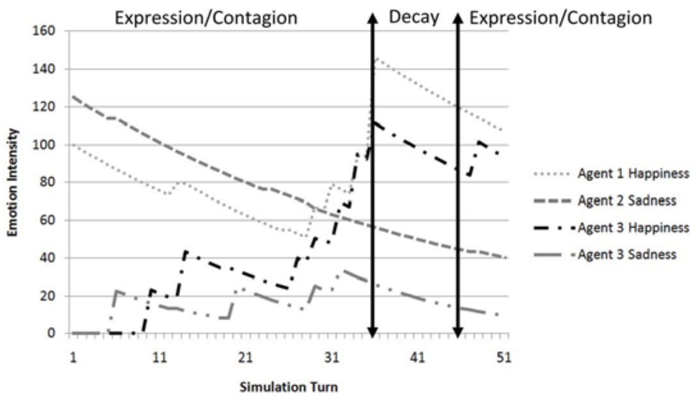

Fig. 2. An example of possible more complex dynamics

the Control scenario with the following differences: there is a relationship with $ri = 1$ and $rpd = 0$ between agents 1 and 3; agent 1 is initially happy with $CM\langle 0, 100, 0, 0, 0\rangle$; agent 2 is initially sad with $CM\langle 0, 0, 125, 0, 0\rangle$.

This simulation starts with 35 turns simulating the process of emotional expression/contagion then 10 turns of simple mood decay (no agent is given the chance to express) and again 5 turns of emotional expression/contagion. In the first part of the simulation we can observe that even though agent 2 has a stronger sadness emotion than agent 1, the intimacy relationship between 1 and 3 biases the EC process in favor of the happiness emotion from agent 1. The upward spiral of happiness continues until turn 35, where agents cease to interact and their emotional levels start decaying altogether. When agents restart to interact on turn 45 the spiraling effect of happiness continues.

6 Conclusions and Future Work

With the presented model we are able to create agents that simulate EC behavior patterns with interpersonal relationships and personality influence. Using our model, a variety of EC phenomenons in groups with intricate relationship networks and different individual characteristics can be simulated. Based on our simulations we verified the intended behaviors by observing the execution patterns throughout a set of individual and group metrics across different scenarios.

Nonetheless, this model can still be improved in a number of directions. One aspect is the manipulation of mixed emotions, instead of just choosing the most intense emotion as the current. The interference between emotions can also be taken into account on the update function, using either a linear model, for instance via a Markov matrix acting on the emotion tuple, or a non-linear one. Furthermore, the presented decay function may be used to create an EC dampening as emotional levels increase in the group.

In combining the influence of interpersonal relationships and personality with the agent's emotional decay, this model is a starting point to the application of EC beyond the area of pure simulation, such as games. A prototype game including it has already been developed and user tests are currently being performed.

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