Social Emotional Model

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Abstract. This article aims to give a first approach of an emotional model, which allows to extract the social emotion of a group of intelligent entities. The emotional model *PAD* allows to represent the emotion of an intelligent entity in 3-D space, allowing the representation of different emotional states. The social emotional model presented in this paper uses individual emotions of each one of the entities, which are represented in the emotional space *PAD*. Using a social emotional model within intelligent entities allows the creation of more real simulations, in which emotional states can influence decision-making. The result of this social emotional mode is represented by a series of examples, which are intended to represent a number of situations in which the emotions of each individual modify the emotion of the group.

1 Introduction

Human-Computer Interaction (HCI) is a field that appeared in the 80s decade, with the Personal Computers, giving access to the new digital technologies and converting all the people in potential users without any knowledge about computers. HCI involves information interchange between people and computers using some kind of dialogue, like programming languages and information interchange platforms. These platforms include from input devices such as keyboards and optical mouses to output devices as the own computer screens. Cognitive psychology integration with HCI field lead to adopt new forms of information processing and to better understanding how people did communicate with the devices. Nevertheless, in spite of the accessibility solutions presented by HCIs, user interfaces were very limited. As a result, the discipline adopt other research subjects focused in usability, ergonomics and to try to build new interfaces allowing a more natural interaction between humans and machines.

These research subjects have made appear new interaction paradigms created by the mobile computing, portable and ubiquitous. They have incorporated devices to communicate directly with the physical world such as movement and gestures capture through the *Kinect* [1] and even user biosignals capture through the *MYO* and *Emotiv* devices [2], [3]. The idea is that machines will not only receive orders from users but also they will perceive their emotional states or behaviors using all this information to execute the different actions [4], [5].

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The information increase generated by the new ways of interaction has made appear the need of using other computational toolkits to classify and process information to benefit user. The AI tools such as pattern recognition ones, automatic learning, and multi-agent systems (MAS) allow the development of this kind of tasks, creating environments that adapt to human needs to improve his welfare and life quality.

Human beings manage themselves in different environments, either in the working place, at home or in public places. At each one of these places we perceive a wide range of stimuli, that interfere in our commodity levels modifying our emotional levels. For instance, the high levels of noise or the temperature conditions may produce stress situations. Before each one of these stimuli, humans answer varying our face gestures, body or bio-electrical ones. These variations in our emotional states could be used as information useful for machines. Nevertheless, it is needed that the machines will have the capability of interpreting or recognizing such variations. This is the reason for implementing emotional models that interpret or represent the different emotions.

Emotional models such as *OCC* [6] presented by *Ortony, Clore & Collins* and the *PAD* model [7] are the most used ones to detect or simulate emotional states. Nevertheless, these models don't allow the execution of intelligent decisions based on the emotional state perception. Between these toolkits, we can find MAS, which are able to modify their behavior based on the emotional state perception. This way, it is obtained that the agent being part of the MAS contains an emotional model able of interpreting and/or emulating different emotional states. To detect emotional states, it is needed to include pattern recognition algorithms, automatic learning contributing to the decision making to execute an action. For instance, if an agent detects that the user presents an emotional state of sadness, it is able to counter that emotional state by executing actions trying to modify it. This way a clean and transparent human-machine interaction is obtained. However, this situation is only valid for a lonely entity inside the environment. The incorporation of more entities inside the environment (multiple emotions) is not contemplated by current emotional models.

The goal of this work is to give a first approach to a social emotional model including multiple emotions between humans and agents. Our model uses as base the *PAD* emotional model to represent the social emotion of a group.

2 Previous Approaches

This section presents an introduction to the emotional models *OCC* and *PAD*. The goal is to give a general view of both emotional models.

2.1 Ortony, Clore & Collins: OCC

The *OCC* model designed by Ortony, Clore & Collins is a model frequently used in applications where an emotional state can be detected or simulated. This has allowed to create applications to emulate emotions in virtual humans [8] and to create agents reacting to stress situations [9].

The *OCC* model specifies 22 emotional categories, which are divided into five processes: 1) the classification of the events, the action or the found object, 2) the quantification of the affected emotions intensity, 3) the interaction between the just generated emotion with the existing ones, 4) the cartography of the emotional state of one emotional expression and 5) is the one expressed by the emotional state [10]. In *OCC* model is observed. These processes define the whole system, where the emotional states represent the way of perceiving our environment (objects, persons, places) and, at the same time, influencing in our behaviour positively or negatively [11]. However, the *OCC* model utilization presents one complication due mainly to his high dimensionality.

2.2 PAD Model

The *PAD* is a simplified model of the *OCC* model. This model allows to represent the different emotional states using three values. These three values are usually normalized in $[-1, 1]$, and correspond to the three components conforming the emotional model (*Pleasure, Arousal, Dominance*). These components can be represented in a $\mathbb{R}^3$ space.

Each one of the components conforming the *PAD* model allow to influentiate the emotional state of an individual in a positive or negative way. This influence evaluates the emotional predisposition of such individual, modifying in this way his emotional state. The Pleasure-Displeasure Scale measures how pleasant an emotion may be. For instance both anger and fear are unpleasant emotions, and score high on the displeasure scale. However joy is a pleasant emotion. This dimension is usually limited to 16 specific values. ([12], pp. 39–53). The Arousal-Nonarousal Scale measures the intensity of the emotion. For instance while both anger and rage are unpleasant emotions, rage has a higher intensity or a higher arousal state. However boredom, which is also an unpleasant state, has a low arousal value. This scale is usually restricted to 9 specific values([12], pp. 39–53).The Dominance-Submissiveness Scale represents the controlling and dominant nature of the emotion. For instance while both fear and anger are unpleasant emotions, anger is a dominant emotion, while fear is a submissive emotion. This scale is also usually restricted to 9 specific values ([12], pp. 39–53).

As have been presented above, the existing emotional models are thought to detect and/or simulate human emotions for a lonely entity. That is, it is not taken into account the possibility of having multiple emotions inside an heterogeneous group of entities, where each one of such entities have the capability of detecting and/or emulating one emotion. The need of detecting the emotion of an heterogeneous group of entities can be reflected in the different applications that could be obtained. With the appearance of the different smart devices, ubiquituous computation and ambient intelligent, emotional states turn into valuable information, allowing to develop applications that help to improve the human being life quality. Therefore, it is needed to create a new model that allow to detect the emotion of a group.

At this point, the two emotional models are used in applications where MAS are is involved, allowing to determine the emotional model *PAD* is most appropriate for our model. This is mainly due to the emotional representation is performed with three normalized values and not 22 as the *OCC* model poses. So as obtaining the quantified emotion of each of the individuals, which allows obtaining total emotion of the agent group. It is for this reason that this work wants to pose a possible solution to this problem, pretending to give a first approximation of a social emotional model based on the *PAD* model on *SEPAD*.

3 Social Emotional Model Based on PAD

This section proposes a model of social emotion based on the *PAD* emotional model. This model will represent the social emotion of a heterogeneous group of entities capable of expressing and/or communicate emotions. To define a model of social emotion, it is necessary first to define the representation of an emotional state of an agent on the *PAD* model. The emotion of an agent ag_i is defined as a vector in a space $\mathbb{R}^3$, represented by three components that make up the *PAD* emotional model. The variation of each component allows to modify the emotional state of the agent (Equation 1).

$$E(ag_i) = [P_i, A_i, D_i] \tag{1}$$

A first approach to of a social emotion representation of a group of n agents $Ag = \{ag_1, ag_2, ..., ag_n\}$ is obtained by averaging their P, A, D values (Equation 2). This average will enable us to determine where the central emotion (CE) of this group of agents and be visualized in the *PAD* space.

$$\bar{P} = \frac{\sum_{i=1}^{n} P_i}{n}, \bar{A} = \frac{\sum_{i=1}^{n} A_i}{n}, \bar{D} = \frac{\sum_{i=1}^{n} D_i}{n} \tag{2}$$

The final result is a vector in the space $\mathbb{R}^3$ which is the core emotion or $CE(Ag)$ of a group of agents (Equation 3).

$$CE(Ag) = [\bar{P}, \bar{A}, \bar{D}] \tag{3}$$

The $CE(Ag)$ by itself is not enough to represent the social emotion of a group of agents, since there may be different groups of agents with the same central emotion but in a very different emotional situation. Figures 1 and 2 [1], show two different situations where the central emotion is the same. In Figure 1 a group of agents is observed with $CE(Ag) = [0.0, 0.22, 0.45]$. In Figure 2 another group of agents is observed with completely different emotions, but generating the same central emotion of the agents shown in Figure 1.

Clearly, the $CE(Ag)$ is not enough to represent the social emotion of an agent group. As it can be seen in the previous example the emotions of an agents

[1] The red triangles represent the different agents, green triangle represents the central emotion $CE(Ag)$ and the blue point refers to (0,0,0).

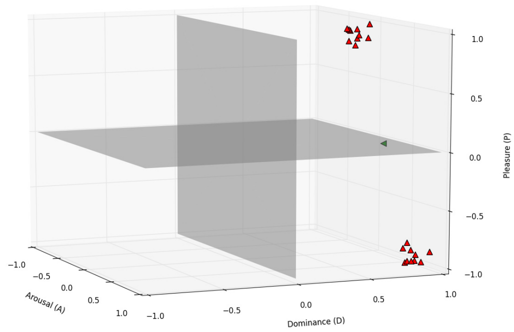

Fig. 1. Group of agents with two subgroups completely opposite

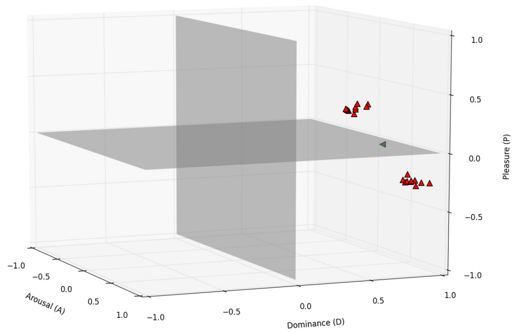

Fig. 2. Group of agents with two subgroups with more nearest emotions

group can be very different but have the same CE. This is why it is necessary to introduce some measurement about the distance of the agents with respect to the CE. To do this we include the definition of the maximum distances of agent emotions respect to $CE(Ag)$. In order to calculate the maximum distances, the Euclidean distance (Equation 4, 5, 6) is used as follows.

$$m_P(Ag) = max\left(\sqrt{(P_i - \bar{P}(Ag))^2}\right), \forall ag_i \in Ag \tag{4}$$

$$m_A(Ag) = max\left(\sqrt{(A_i - \bar{A}(Ag))^2}\right), \forall ag_i \in Ag \tag{5}$$

$$m_D(Ag) = max\left(\sqrt{(D_i - \bar{D}(Ag))^2}\right), \forall ag_i \in Ag \tag{6}$$

The results of these equations can be represented as a vector of maximum distances (Equation 7).

$$m(Ag) = [m_P(Ag), m_A(Ag), m_D(Ag)] \quad (7)$$

The $m(Ag)$ can indicate if there exist agents having their emotional state far away from the central emotion. From a graphical perspective it is also possible to use these maximum distances to plot an enveloping which encapsulates all emotions, allowing the limit of all the agents to be defined. To represent this enveloping shape of emotions an ellipsoid as a geometric figure was used. This ellipsoid (Figure 3) [2] can be adapted to represent different emotional states, which allows a dynamical way for displaying the social emotion of a group.

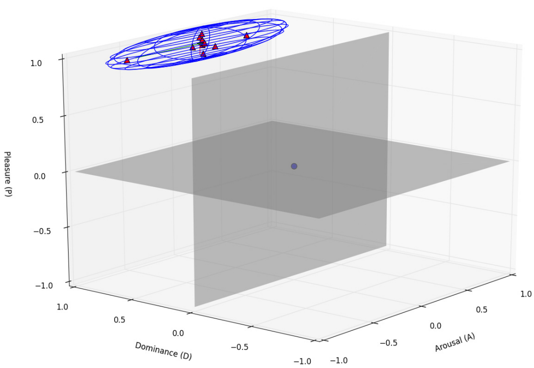

Fig. 3. Ellipsoid enveloping the emotions of a group of agents

Furthermore, considering $m(Ag)$ as a part of the definition of the social emotion of a group of agents, there may be situations in which $m(Ag)$ is not enough. In Figure 4 and 5 a group of agents is shown with similar $CE(Ag)$ and $m(Ag)$, but with completely different emotional situations. In order to solve this problem the notion of standard deviation (SD) is introduced. This SD allows the calculation of the level of emotional dispersion of this group of agents around the central emotion $CE(Ag)$ for each component of the PAD(Equation 8).

$$\begin{aligned}
\sigma_P(Ag) &= \sqrt{\frac{\sum_{i=1}^{n}(P_i - \bar{P}(Ag))^2}{n}}, \forall ag_i \in Ag \\
\sigma_A(Ag) &= \sqrt{\frac{\sum_{i=1}^{n}(A_i - \bar{A}(Ag))^2}{n}}, \forall ag_i \in Ag \\
\sigma_D(Ag) &= \sqrt{\frac{\sum_{i=1}^{n}(D_i - \bar{D}(Ag))^2}{n}}, \forall ag_i \in Ag
\end{aligned} \quad (8)$$

[2] This figure is a snapshot of the emotion of a group of agents in a specific time

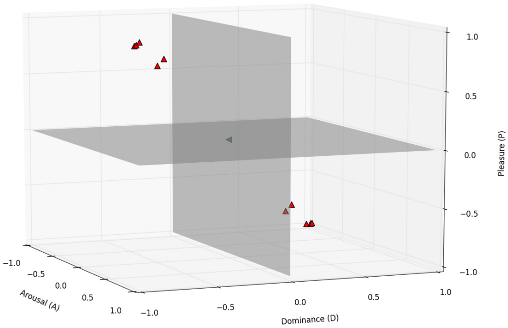

Fig. 4. Group of agents with two subgroups with central emotion different but equal maximum distances

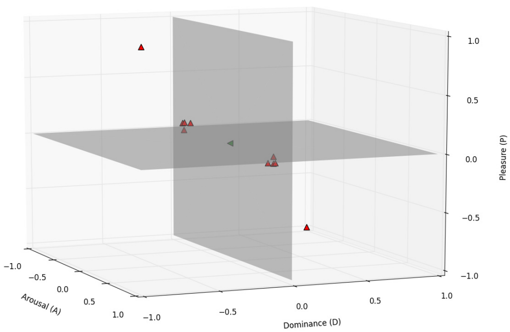

Fig. 5. Group of agents with two subgroups with central emotion different but equal maximum distances

The result of each of the above equations can be represented as a vector (Equation 9), which allow to determine the level of emotional dispersion.

$$\sigma\,(Ag) = [\sigma_P(Ag), \sigma_A(Ag), \sigma_D(Ag)] \tag{9}$$

From this definition, it can be deduced that:

1. **if** $\sigma\,(Ag) >> \mathbf{0}$, the group has a high emotional dispersion, i.e. the members of the group have different emotional states.
2. **if** $\sigma\,(Ag) \cong \mathbf{0}$, the group has a low emotional dispersion, this means that individuals have similar emotional states.

Adding the emotional dispersion in the definition of the social emotion of a group of agents, the social emotion of a group of agents $Ag = ag_1, ag_2, ..., ag_n$ can be defined by the following triplet (Equation 10).

$$SE(Ag) = (CE(Ag), m(Ag), \sigma(Ag)) \tag{10}$$

Where $CE(Ag)$ is the central emotion, $m(Ag)$ represents the maximum distances and $\sigma(Ag)$ represents the emotion dispersion of an agent group.

Based on this model it is possible to determine the emotional distance among different groups of agents or between the same group in different instants of time. This will allow to measure the emotional distance between the current social emotional group and a possible emotional target. This approach can be used as a feedback in the decision making process in order to take actions to try to move the social emotion to a particular area of the PAD space or to allow that the emotional state of a group of agents can be approached or moved away from other groups of agents. From an emotional point, of view these movements or actions are domain-dependent and are out of he scope of this model. In Equation 11 the profile of the emotional distance function is defined as the distance of the social emotions of two groups of agents.

$$\Delta_{SE} : SE(Ag^i), SE(Ag^j) \rightarrow [0, 1] \tag{11}$$

According to this profile, Equation 12 shows how we calculate this emotional variation. The equation calculates three distances corresponding to the three components of the *SE*. Given two groups of agents Ag_i, Ag_j with social emotions $SE(Ag^i), SE(Ag^j)$ respectively, the emotional distance between these two groups is calculated as:

$$\begin{aligned} \Delta_{SE}(SE(Ag^i), SE(Ag^j)) = \frac{1}{2}\Big(&\omega_c \Delta(CE(Ag^i), CE(Ag^j)) \\ &+\omega_d \Delta(m(Ag^i), m(Ag^j)) \\ &+\omega_v \Delta(\sigma(Ag^i), \sigma(Ag^j))\Big) \end{aligned} \tag{12}$$

$$where \quad \omega_c + \omega_d + \omega_v = 1; \quad \omega_c, \omega_d, \omega_v \in [0, 1] \tag{13}$$

and Δ calculates the vectorial distance between two vectors. As every dimension of the PAD space is bounded between $[-1, 1]$, each Δ will give values between $[0, 2]$. Therefore, Δ_{SE} will have a range between $[0, 1]$.

Calculating the distance among social emotions allows the study of the behavior of emotional-based agents, either minimizing or maximizing the $\Delta_{SE}(SE(Ag^i), SE(Ag^j))$ function. This way, it can be achieved that an agent group approaches or move away of an specific emotional state. To do this it is necessary to modify through stimuli the individual emotions from each agent and therefore changing the social emotion. Nevertheless, how to maximize or minimize the emotional distance is domain-dependent and it is out of the scope of this paper.

4 Case Study

A practical application which uses the previously proposed model is presented in this section. This application example is based on how music can influence in a positive or negative way over emotional states [13], [14], [15].

The application example is developed in a bar, where there is a DJ agent in charge of play music and a specific number of individuals listening the music. The main goal of the DJ is to play music making that all individuals within the bar are mostly happy as possible. Each of the individuals will be represented by an agent, which has an emotional response according to its musical taste. That is, depending on the musical genre of the song, agents will respond varying their emotional state. Moreover, varying emotions of each agent will modify the social emotion of the group. The different scenarios have been designed in order to show how the social emotion can facilitate the decision making of the DJ. In each scenario the DJ agent plays a song. Once the song has ended, the DJ evaluates the social emotion of the group of listeners that are within the bar. In this way, the DJ agent can evaluate the effect that the song has had the song over the audience. This will help the DJ to decide whether to continue with the same musical genre or not in order to improve the emotional state of the group.

4.1 Scenario 1: Group of Agents with Low Emotional Dispersion

The first case analyzed is one in which the emotional states of the agents are close. This emotional difference may be due mainly because the agents have little differences in their musical tastes. The social emotion in this scenario has a $EC(Ag)$ very close to all the values of the agents and the $m(Ag)$ and $\sigma(Ag)$ values will be very small and in many cases close to zero. This provokes that the DJ will try to play songs of similar generes trying to maintain this situation, which is not the ideal situation but it can be considered as a very good situation. A graphical representation of this example can be seen in Figure 6 while Table 1 shows the different emotional states of each of the agents in this group.

Table 1. Individual emotion of each agent and its magnitude in the PAD space

Agents	P	A	D	Emotional State
ag_0	0.90	0.0	0.90	Happy
ag_1	0.70	0.0	0.91	Happy
ag_2	0.80	0.0	0.95	Happy
ag_3	0.85	0.0	0.99	Happy
ag_4	0.91	0.0	0.89	Happy
ag_5	0.93	0.0	0.86	Happy
ag_6	0.89	0.0	0.83	Happy
ag_7	0.79	0.0	0.81	Happy
ag_8	0.92	0.0	0.89	Happy
ag_9	0.81	0.0	1.0	Happy

As it can be see in the Figure 6 all the represented emotions in this group are around the emotion *Happy*, achieving a social emotion with these values of $SE(Ag) = ([0.85, 0.0, 0.9], [0.85, 0.0, 0.9], [0.07, 0.0, 0.06])$.

4.2 Scenario 2: Group of Agents with High Emotional Dispersion

In this second case it is represented the existence of a group of agents emotionally dispersed in the bar. These agents have completely different emotions

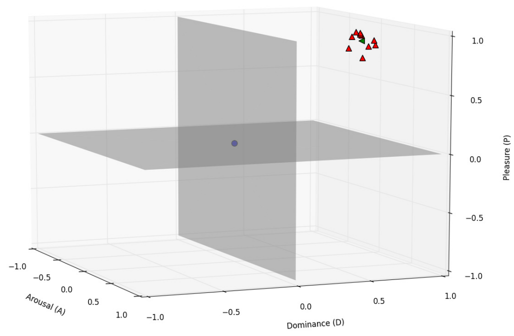

Fig. 6. Scenario 1: Group of agents with low emotional dispersion

Table 2. Individual emotion of each agent and its magnitude in the PAD space

Agents	P	A	D	Emotional State
ag_0	-0.9	-0.9	-0.9	Remorse
ag_1	-0.7	0.6	0.0	Anguish
ag_2	0.9	0.9	0.0	Joy
ag_3	0.9	-0.5	0.9	Satisfaction
ag_4	-0.7	0.8	-0.9	Hurt
ag_5	0.9	0.9	0.9	Admiration
ag_6	0.9	0.0	0.9	Happy
ag_7	-1.0	1.0	0.9	Anger
ag_8	1.0	1.0	-0.9	Love

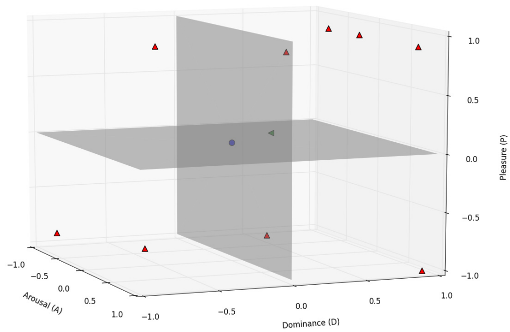

Fig. 7. Scenario 2: Group of agents with high emotional dispersion

distributed along the *PAD* space. The emotional values of each of the agents can be seen in Table 2. This high dispersion is reflected in the calculated values of the social emotion ($SE(Ag) = ([0.14, 0.42, 0.1], [1.14, 1.32, 1.0], [0.87, 0.67, 0.79])$. In this case, the social emotion is very different and more complicated to manage then the previous case. The central emotion is very far from the emotional states of each agent and the maximum distances and dispersion values are high too.

So, from the perspective of the DJ this scenario is very chaotic and unwished because it is difficult to choose which kind of music is the most appropriated. In this case the DJ should try to move the central emotion to a state close to "happy" testing different musical styles and analyzing carefully the effect of each song in the social emotion of the group.

5 Conclusions and Future Work

A new model for representing social emotions has been presented in this paper. The goal of this model is to give a first approach for the detection and simulation of social emotions in a group of intelligent entities. This social emotion model builds on the *PAD* emotional model, which allows the representation of individual emotions in intelligent entities. The proposed model of social emotion uses the individual emotions of each entity of a group, allowing us to represent the emotion of that group as a triplet consisting of three vectors $(EC(Ag), m(Ag) and \sigma(Ag))$. This definition allows us to represent the emotional state of a group of entities that are placed in a specific environment. Moreover, the model adds the mechanisms to compare the social emotional state of two groups of agents or the social emotion of a group in different time instants. The social emotion of a group of agents not only allows a global view of the emotional situation of the group, moreover it can be used as a feedback in order to change the emotional state of the group or only of a part of the agents. As future work we want to introduce the human within the model, adding their emotional state through the analysis of body gestures or through the face. To do this, specialized hardware must be used in order to obtain this information, helping to create environments in which humans interact in a transparent way with intelligent entities employing their emotional states.

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