Sharing Emotional Information Using A Three Layer Model

Imen Tayari Meftah[1,2] and Nhan Le Thanh[1]
[1]*University of Nice Sophia Antipolis and CNRS*
I3S Laboratory
Sophia Antipolis, France
Email: tayari@i3s.unice.fr, nhan.le-thanh@unice.fr

Chokri Ben Amar[2]
[2]*University of Sfax and ENIS*
REGIM laboratory
Sfax, Tunisia
Email: chokri.benamar@enis.rnu.tn

***Abstract*—In this study, we present a generic model to exchange emotional states information between heterogeneous multi-modal applications. Our proposal is composed of three distinct layers: the psychological layer, the formal computational layer and the language layer. The first layer represents the psychological theory adopted in our approach, The second layer is based on a formal multidimensional model. It matches with the psychological approach of the previous layer. The final layer uses XML to generate the final emotional data to be transferred through the network. The remainder of this article describes each layer of our model. The proposed model enables the exchange of the emotional states regardless to the modalities and sensors used in the detection step. Moreover our model permits to model not only the basic emotions (e.g., anger, sadness, fear) but also different types of complex emotions like simulated and masked emotions.**

***Keywords*-emotion, multimodality, three layers model, Plutchik model, emotional exchanges, multidimensional spaces.**

I. INTRODUCTION

The use of emotion in computers is becoming an increasingly important field for human-computer interaction. Indeed, affective computing is becoming a focus in interactive technological systems and more essential for communication, decision-making and behavior. There is a rising need for emotional state recognition in several domains, such as health monitoring, video games and human-computer interaction. The emotional information exchange between applications entails many problems such as application heterogeneity, complexity of emotional states, diversification of capture tools and dependence between treatment and physical sensors. The lack of a standard in human emotions modeling hinders the sharing of affective information between applications. As part of the research project Emotica, we define a generic model facilitating communication between heterogeneous multi-modal applications. Our proposal is composed of three distinct layers: the psychological layer, the formal computational layer and the language layer. This generic model is designed to be usable in a wide range of use cases, including modeling and representation of Emotional States. In this paper, we explain the role of each layer of our generic model. The remainder of this paper is organized as follows. In Section 2, we present the problem statement. In Section 3, we describe the different parts of our model. Finally, we conclude in Section 4.

II. PROBLEM STATEMENT

Emotions are an important key component of human social interaction. Today there is a need for computers to understand this component in order to facilitate communication between users and to improves the credibility of interactions human-computer. Sharing emotional states becomes more and more important in human-machine interactive systems. Nevertheless, it entails many problems due to complexity of emotional states, diversification of capture tools and dependence between treatment and physical sensors. Emotion is a complex concept. Indeed there is no agreed model for the representation of emotional states. Many theories focused only on basic emotions [1]. Another ones introduced some complex emotions [2] but does not encompass all the emotional states. Moreover, in a natural setting, emotions can be manifested in many ways and, expressed and perceived through multiple modalities, such as facial expression ,gesture, speech, or physiological variation. Each modality need a specific processing and use special techniques for the recognition step. The difficulty of sharing emotional information between many applications which use different modalities coming from the dependance between treatment and physical sensors and the lack of a standard human emotions modeling.

Current works on modeling and annotation of emotional states like Emotion Markup Language (EmotionML) [3] or Emotion Annotation and Representation Language (EARL) [4] aim to provide a standard for emotion exchange between applications, but they use natural languages to define emotions. They use words instead of concepts. For example, in EARL, joy would be represented by the following string ”<emotion category=”joy” />”, which is the English word for the concept of joy and not the concept itself, which could be expressed in all languages (e.g., joie, farah, gioia). In this article, we propose a generic model, which can model any kind of complex emotion, and permits the exchange of emotional states between heterogeneous applications regardless to the modalities and sensors used in the detection step.

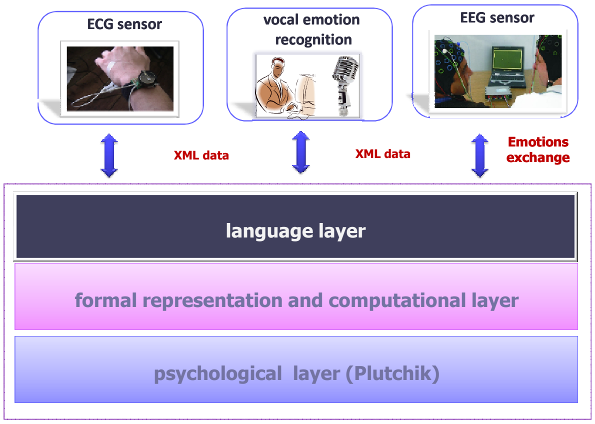

Figure 1. The Three-layer model

III. The Proposed Model

Our approach is based on a hierarchical representation model composed by three distinct layers which are interdependent to ensure a maintenance of coherence of the model. Figure 1 shows a global schema of our proposed model. It is composed of three distinct layers: the psychological layer, the formal representation layer and the language layer.

A. The psychological layer

The psychological layer is the first layer of our model and it represents the psychological model that we chosen to represent the emotional state of users. Emotion is a complex concept. There is no consensus among psychological and linguistic theories on emotions. According to research in psychology, three major approaches to affect modeling can be distinguished [5]: dimensional, categorical, and appraisal-based approach. The dimensional approach models emotional properties in terms of emotion dimensions. It decomposes emotions over two orthogonal dimensions, namely arousal (from calm to excitement) and valence (from positive to negative) [6]. In the Appraisal theory, emotions are obtained from the subjective evaluations (appraisals) of events/stimulus that cause specific reactions in different people. Finally, categorical approach focus on identifying a small number of primary and distinct emotions. the number of basic emotions varies from one theory to the next: for instance, there are 6 basic emotions in the Fridja's theory [7], 9 in the Tomkins's theory [8] and 10 in the Izard's theory [9]. Plutchik proposed a three-dimensional circumplex model (Figure 2) which describes the relationships between emotions. His model is very intuitive and easy including the idea that complex emotions are obtained by mixing primary ones. We opted for his approach as the basis of our model and will thus describe it in details.

1) Plutchik model: Robert Plutchik adopted a color metaphor for the combination of basic emotions [10]. He proposed a three-dimensional "circumplex model" (Figure 2), which describes the relationships between emotions. He argued for eight primary emotion arranged as four pairs of opposites: (Joy-Sadness, Fear-Anger, Surprise-Anticipation, Disgust-Trust) [10]. The vertical dimension represents intensity or level of arousal, and the circle represents degrees of similarity among the emotions. He suggested that nonbasic emotions are obtained through the addition of basic emotions (color analogy, Plutchik, 1962) [11]. In his model, for instance, Love = Joy + trust and Delight = Surprise + Joy. Plutchik defined rules for building complex emotions out of basic ones. In practice, combination of emotions follows the method "dyads and triads" [12]. He defined the primary dyads emotions as the mixtures of two adjacent basic emotions. Secondary dyad includes emotions that are one step apart on the "emotion wheel", for instance Fear + Sadness = Despair. A tertiary emotion is generated from a mix of emotions that are two steps apart on the wheel (Surprise + Anger = Outrage).

In our work, we chose the Plutchik model to represent the psychological layer because it verifies many important conditions for the elaboration of our model and it explains emotions in terms of formulas that can be universally applied to all human beings [13]. First, the Plutchik model is based on 8 basic emotions encompassing the common five basic emotions. Then, it takes into account the intensity of emotion i.e., the level of arousal or the feeling degree of each basic emotion for example (terror, fear, apprehension). Finally, the Plutchik model is intuitive, very rich and it is the most complete model in literature because it permits to model complex emotions by using basic ones. Indeed, as we have seen, Plutchik defined the dyads and the triads which are combinations of basic emotions describing complex emotions which are regarded as emotions in usual life.

B. The formal computational layer

The formal computational layer is the second layer of our model. It matches the psychological approach of the first layer. It is the formal representation of Plutchik's model and it is based on an algebraic representation using multidimensional vectors. In this layer, we represent every emotion as a vector in a space of 8 dimensions where every axis represents a basic emotion defined on the Plutchik theory .

First, we define our Base by (B) = (joy, sadness, trust, disgust, fear, anger, surprise, anticipation), which are the basic emotions on the Plutchik theory. So every emotion (e) can be expressed as a finite sum (called linear combination) of the basic elements.

$$(e) = \sum_{i=1}^{8} \langle E, u_i \rangle u_i \tag{1}$$

Thus, $(e) = \alpha_1 Joy + \alpha_2 sadness + \alpha_3 trust + .. + \alpha_7 surprise + \alpha_8 anticipation$
where α_i are scalars and $u_i (i = 1..8)$ elements of the basis

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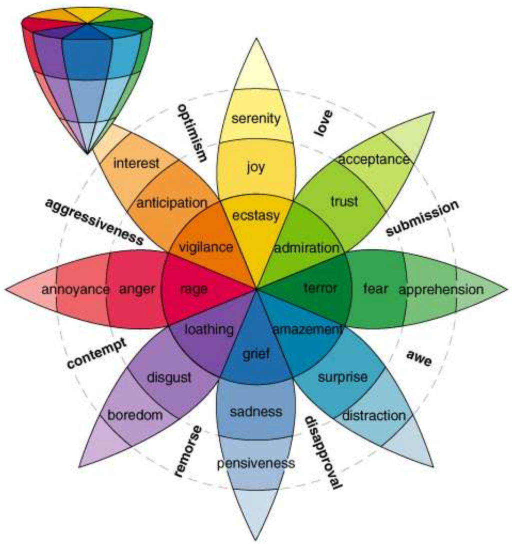

Figure 2. Plutchiks three-dimensional circumplex model

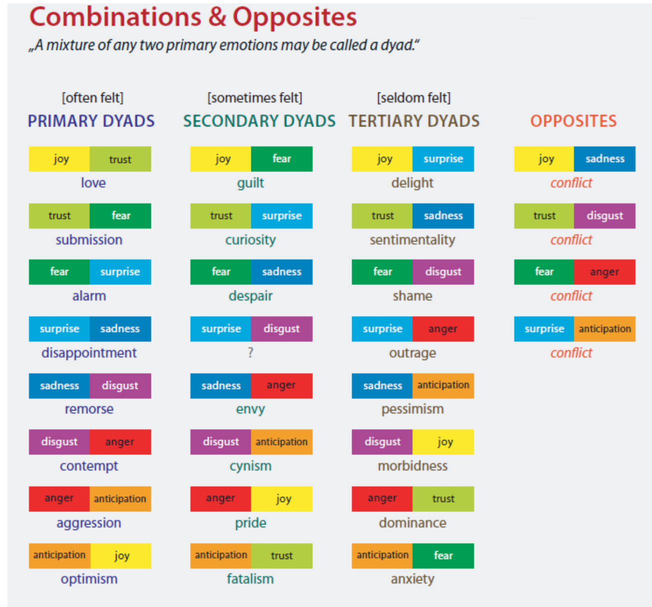

Figure 3. Combination and opposites on the Plutchik's model

(B). Typically, the coordinates are represented as elements of a column vector E

$$E = \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ . \\ . \\ \alpha_8 \end{pmatrix}_B$$

where $\alpha_i \in [0,1]$ represent the intensity of the respective basic emotion. More the value of α_i gets nearer to 1, more the emotion is felt.

The proposed model takes into account the property of the intensity of the emotion. Indeed, each emotion can exist in varying degrees of intensity. The coefficients α_i determine the emotion intensity. According to the value of the coefficients α_i we can make the difference between annoyance, anger and rage or pleasure, joy and ecstasy. So, rage is the basic emotion anger with high intensity. The multidimensional representation of the formal computational layer provides the representation of an infinity of emotions and provides also a powerful mathematical tools for the analysis and the processing of these emotions. Indeed we can apply the usual basic algebraic operations on vectors like the addition, the scalar multiplication, the projection and the distance in an Euclidean space. We are going to detail only the addition, and the Euclidean distance. for more detail you can see [14].

1) Vector addition: We have seen in the previous paragraphs that the mixture of pairs of basic emotions resulted of complex emotion. Joy and trust for example produce the complex emotion "love". In this part we define the combination between emotions as the sum of two emotion vectors. This addition is defined as the maximum value of coefficients (term by term) [14]. Let E_{1u} and E_{2u} be two emotional vectors expressed in the basis (B) respectively by $(\lambda_1, \lambda_2, .., \lambda_8)$ and $(\lambda_1^{'}, \lambda_2^{'}, .., \lambda_8^{'})$. The addition of these two vectors is defined as:

$$E^{'} = E_{1u} \bigoplus E_{2u} = \max(\lambda_i, \lambda_i^{'}) for 0 \leq i \leq 8 \quad (2)$$

In this sense, the vector representing the emotion love, which is mixture of joy and trust, is defined as:

$$E_{love} = E_{Joy} \bigoplus E_{trust}$$

$$E_{love} = \begin{pmatrix} \alpha_1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}_B \bigoplus \begin{pmatrix} 0 \\ 0 \\ \alpha_3 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}_B = \begin{pmatrix} \alpha_1 \\ 0 \\ \alpha_3 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}_B$$

where $\alpha_1 \neq 0 \ et \ \alpha_3 \neq 0$

In the same way we can obtain the "vector form" of the other complex emotions states defined by Plutchik. These emotions combinations are shown on Figure 3. Figure 4 shows an example of the using of the add operation on application of emotion detection. On this example the detection is done using two modalities. Each modality gives an emotion vector. The vector V_1 is given by the facial modality and the vector V_2 is given by the physiological modality. The final emotion vector V_f is given by the addition of this two vectors using equation 2.

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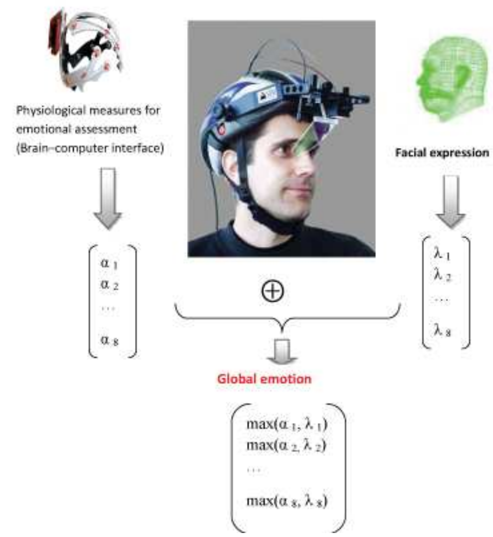

Figure 4. Multi-modality emotion recognition system

2) Euclidean distance (2-norm distance):

$$d(E,Y) = \sqrt{\sum_{i=1}^{n}(y_i - x_i)^2} \quad (3)$$

with E $\begin{pmatrix} x_1 \\ x_2 \\ . \\ . \\ x_n \end{pmatrix}_B$ and Y $\begin{pmatrix} y_1 \\ y_2 \\ . \\ . \\ y_n \end{pmatrix}_B$ are two vectors.

The proposed model is a continuous model providing the representation of infinity of emotions. Thus, to analyse a given vector and determine the nearest emotion from the known ones we need a tool to calculate the similitude from the vector and the known emotions. For this, we propose to use the Euclidean distance (2-norm distance) defined by equation 3. First, we have to generate a data base of emotions composed by the vectors of all emotions proposed by Plutchik given by Figure 2 and Figure 3. So, our emotion data base is composed by approximately 50 emotions and can be extended by others emotions. Then we have to compute for a given vector V1 the Euclidean distance between it and all the vectors of the data base. Finally we keep the vector of the data base minimizing this distance. This vector represents the nearest emotion of V1 and the computed distance gives an idea of the precision of this interpretation. For example, we can found that the nearest emotion for the vector V1 is ”love” with a distance equals to zeros. We can affirm without doubts that V1 represents the emotion ”love”. More the distance from the nearest vector is important, less the interpretation is accurate. So the proposed method, using the Euclidean distance, permits to analyse automatically a given vector and provides the best interpretation of this vector.

C. The language layer

The third layer of our model is the language layer. This layer provides encoding emotional information. We propose to use the eXtensible Mark-Up Language (XML) developed by the World Wide Web Consortium to annotate and represent emotional states of users.

XML, is a method for describing and encoding data. It is used for representation and transmission of data between application and organization. It is a text-based system meaning that both humans and machines can understand it directly, and is self-describing in so much as each data element can be traced to a definition [15]. For example, annotating a complex emotion detected using the voice modality (microphone) give the following XML structure:

<emotion>
<modality set= ”basic-modality” >
<vector mode=”voice”>
<intensity axis=”joy”>0.8</intensity >
<intensity axis=”sadness”>0.0</intensity >
<intensity axis=”trust”>0.6</intensity >
<intensity axis=”disgust”>0.0</intensity >
<intensity axis=”fear”>0.0</intensity >
<intensity axis=”anger”>0.0</intensity >
<intensity axis=”surprise”>0.0</intensity >
<intensity axis=”anticipation”>0.0</intensity >
</vector>
</emotion>

The numeric values for the tag ”intensity ” indicate the intensity of the respective basic emotion going on, on a scale from 0 (emotion is not felt) to 1 (more the emotion is felt). Using the computational layer we can conclude that the felt emotion is a complex one because there is more than one axis with a value different from zeros. Moreover, using our algorithm based on the Euclidean distance, defined on the formal computational layer, we can conclude that the felt emotion is ”love”.

The next example was generated using two modalities: the heart rate modality and the facial expression modality. Each modality will give a vector with different coefficients.

<emotion>
<modality set= ”multi-modality” count=”2”>
<vector mode=”heart-rate”>
<intensity axis=”joy”>0.0</intensity >
<intensity axis=”sadness”>0.4</intensity >
<intensity axis=”trust”>0.0</intensity >
<intensity axis=”disgust”>0.0</intensity >
<intensity axis=”fear”>0.8</intensity >
<intensity axis=”anger”>0.2</intensity >

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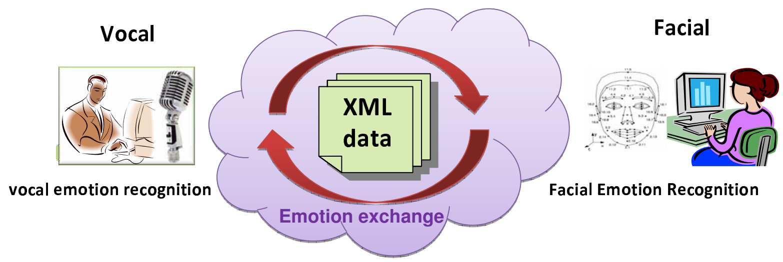

Figure 5. An example of sharing emotional states.

<intensity axis=”surprise”>0.0</intensity >
<intensity axis=”anticipation”>0.0</intensity >
</vector>
<vector mode=”face”>
<intensity axis=”joy”>0.0</intensity >
<intensity axis=”sadness”>0.7</intensity >
<intensity axis=”trust”>0.0</intensity >
<intensity axis=”disgust”>0.0</intensity >
<intensity axis=”fear”>0.1</intensity >
<intensity axis=”anger”>0.0</intensity >
<intensity axis=”surprise”>0.0</intensity >
<intensity axis=”anticipation”>0.0</intensity >
</vector>
</emotion>

In the last example, each modality gives a separate vector. Using the vector addition of the computational layer, we obtain the final vector describing the felt emotion

$$E = \begin{pmatrix} 0 \\ 0.7 \\ 0 \\ 0 \\ 0.8 \\ 0.2 \\ 0 \\ 0 \end{pmatrix}_B$$

The next step is to apply the distance algorithm to determine the most similar emotion of the data base to our vector. Figure 5 shows an example of exchanging emotional information between two users using our model. The first user (user1) uses a camera to detect emotions. The emotion detected using the facial expression is represented in XML data and sent to (user2). User2 analyses the xml data and uses our algorithm based on the Euclidean distance to find that the felt emotion by (user1) is ”shame” and vice versa. we notice that (user2) can determine the emotion felt by (user1) regardless the modality used on the detection step and he can share emotional data with everyone without restriction. Moreover, this emotional information can be exploited by different application like 3D video games or serious games monitoring.

IV. Conclusion and Open Issues

We have presented a generic model allowing the communication between various multi-modal applications. Our model is based on psychology research. It is composed of three distinct layers which are interdependent to ensure a maintenance of coherence of the model. The vectorial representation of emotions on the middle layer of our model allows powerful mathematical tools for the analysis and the processing of these emotions like addition (Figure 4), projection and decomposition [14]. This new model allows a transparent transfer of emotional states information between heterogeneous applications regardless to the modalities and sensors used in the detection step and provides the representation of infinity of emotions. For the future work, we would extend our model with adding another layer containing information relative to the user such as personality traits, social relations and emotional context.

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