Making Empathetic Virtual Humans in Human-Computer Interaction Scenarios

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***Abstract*—This paper presents a system that enables a virtual human to express emphatic emotions as a response to the emotions of a user. In this system, we use a real-time video as input, where the face of a user is tracked to recognize its emotions and generate the corresponding reactions from a virtual human.**

I. Introduction

By nature, human being is able to recognize emotions of other persons from facial expressions. This ability plays an important role in human-human communication. In this way, facial expressions are a key element of human interaction, which give evidence of six emotions universally recognized, namely happiness, surprise, fear, sadness, anger and disgust [3]. However, the body language (gestures and postures) and the tone of voice represent other media for emotion recognition. These media provide both verbal and non-verbal information, which represent an alternative to generate and propose new paradigms and models in human-computer interaction (HCI).

Research in the psychological field has demonstrated that emotions, gestures, postures and facial expressions play a central role in human communication in the face of different emotional situations. Affective computing deals with the problem of designing computer systems and devices that recognize human emotions. Recognizing emotional information by using methods based on facial expression recognition or natural language processing will make the computer systems more effective at communicating with human beings.

In this work, we present a methodology based on the Emotional Intelligence (EI) Model [4] to develop empathic virtual humans with the capacity to recognize emotions and to express empathy when interacting with users. These cognitive skills are: the ability of a virtual human to recognize the emotional state of a user and its capability to modulate its emotional and mood state according with the emotions of a user in order to give an empathic emotional response.

According to Hoffman [6], there are two types of empathy for different situations. The first one represents the cognitive awareness of the internal states of other persons (perceptions, feelings, intentions and thoughts). The second one is an affective reaction or response to other person that can be more appropriate and congruent for the situation of other person than for the situation of oneself. Thus, empathy is a key component of social interaction. However, in this paper, we only take into account the second type called affective empathy. Thus, a virtual human can feel what user feels. Therefore, empathy represents a motivational basis of pro-social behavior of virtual human with the user, but it not necessarily reproduces the emotions of user in the virtual human.

This paper has the following structure: the next section presents an overview of the related work. The third section describes our approach, which is based on the EI model. In the fourth section, we present the implementation of our system. Finally, in the last section we present our conclusions.

II. Related Work

Recent studies in affective reasoning have demonstrated that emotions play a central role in human cognition. The obtained results also indicate that these are equally important in the development of emotionally intelligent agents. In HCI, there is a growing demand for interactive technologies to create engaging experiences for increasingly sophisticated users. In recent years, remarkable progresses based on synthetic agents inhabiting interactive systems have been obtained.

The main objective in creating empathic models for virtual humans is to improve the HCI. For example, some applications are used to facilitate education in virtual environments [1] [7] or reducing frustration in users [2]. The most important aspects to consider empathy [6] in a HCI scenario are: user emotional cues recognition, for example, based on facial expression recognition [17], interpretation of these cues, and an emotional response on behalf of the computer (emotional agent) [8].

New advances in emotional behavior and affective reasoning play an important role in HCI [9] [10]. These advances cover mainly, the design of synthetic agents [11] and embodied conversational agents [12], the empathy in synthetic agents as an affective response in a communicative emotional context [13], and the interaction between agents with the user in a virtual learning environment to express empathetic behaviors [14]. Other approaches use probabilistic models to assessing the affective state of users in educational games [15] to investigate the role of affect and social factors in pedagogical agents [16].

Table I
EMPATHY RULES FOR A VIRTUAL HUMAN IN A HCI SCENARIO

Rule	Emotion of the user	Emotional response of virtual human
1	anger	anger, disgust, fear, sadness, surprise
2	disgust	anger, fear, surprise disgust, sadness
3	fear	fear, surprise
4	happiness	happiness, surprise
5	sadness	fear, sadness, surprise
6	surprise	fear, happiness, surprise

III. EMOTIONAL INTELLIGENCE MODEL

We use the Emotional Competence Framework (ECF) presented in [4] in order to implement the emotional competencies of a virtual human (skills based on EI). Thus, the EI of a virtual human is its ability to understand, distinguish and manage its emotions, and to recognize and interpret the emotions of other entities (for example, a user or other virtual human). In order to develop this cognitive capacity, we have only implemented the following emotional competencies.

A. Self-Consciousness

This competence represents the ability of a virtual human to perceive and reason about itself and its environment. That is to say, it is the understanding of its environment and its self-knowledge. We represent this competence by using a knowledge base (ontology) that contains the necessary concepts to give the virtual human a self-knowledge. These elements include mainly: personality, emotional and mood states, morphology and anthropometry description, and motion skills.

B. Social Awareness or Social Consciousness

In order to develop this competence, a virtual human assesses the perceived affective state of a user to produce different affective outcomes. Figure 1 shows that the reactive outcomes could be the combination of facial and corporal animation sequences (visual information), audio sequences (verbal information) and text sequences (textual information). However, in this work, we only implemented facial expression outcomes. To do this, we have defined six basic rules that constrain these outcomes to avoid undesired or incoherent responses. These rules are illustrated in the next table:

C. Self-Regulation

This competence is the ability of a virtual human to regulate its internal states (emotions and moods) and external states (corporal motions and facial expressions). In order to implement this competence, we propose a variant and improvement of the generic personality and emotion simulation model presented in [5] to update the emotional and mood state of a virtual human in a better way. To carry out this, we use

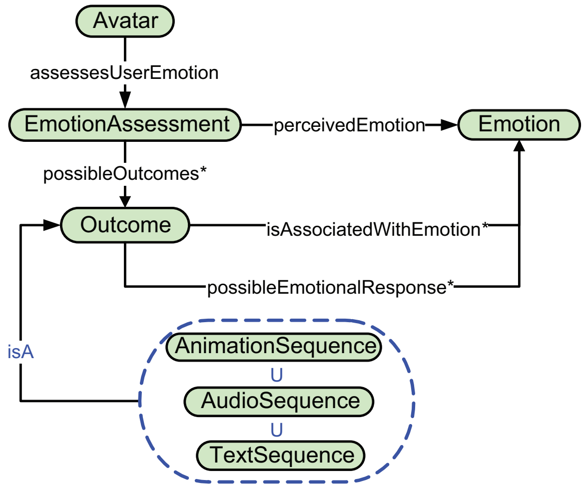

Figure 1. Assessment of the Emotions of a User to Produce a Coherent Reactive Outcome in a Virtual Human in a HCI Scenario

the OCEAN model of personality [18], the six universal basic emotions (anger, disgust, fear, happiness, sadness and surprise) [3] and three basic moods (good, neutral and bad) to represent the personality, and emotional and mood state of a virtual human, respectively. In our model, we define a virtual human as an avatar in the following way:

$$A_t = (R, p, e_t, m_t) \tag{1}$$

where R is the self-consciousness of an avatar (its cognitive awareness), p is its personality, and, e_t and m_t are its emotional and mood state at time t. Personality p is always constant and it is represented by the following vector:

$$p^T = [o, c, e, a, n], o, c, e, a, n \in [0, 1] \tag{2}$$

where these personality values represent the level of intensity of openness (o), conscientiousness (c), extroversion (e), agreeableness (a), and neuroticism (n) of a virtual human.

Emotional state e_t always changes over time and it represents the intensity of the basic emotions at each time t. These emotions are labeled as: a (anger), d (disgust), f (fear) h (happiness), sa (sadness) and su (surprise) in a 6-dimensional vector as follows:

$$e_t^T = \begin{cases} [a, d, f, h, sa, su] & \text{if } t > 0 \\ 0 & \text{if } t = 0 \\ a, d, f, h, sa, su \in [-1, 1] & \end{cases} \tag{3}$$

In a similar way to the emotional state, the mood state m_t changes over time and it represents the intensity of three basic moods at each time t. These moods are labeled as: g (good), n (neutral) and b (bad) in a 3-dimensional vector in the following way:

$$m_t^T = \begin{cases} [g, n, b], g, n, b \in [-1, 1] & \text{if } t > 0 \\ 0 & \text{if } t = 0 \end{cases} \tag{4}$$

We also use an emotional history ω_t and a mood history σ_t that contain the emotional states e_0 until e_t and the mood states m_0 until m_t, respectively. The next step is to update the emotional and mood state. We use a vector of emotional influence a. This vector contains a desired change of intensity for each of the six emotions of an avatar. In order to update the emotional state, we apply the defined rules in the previous section. For all the possible outcomes, the desired change of intensity for each possible emotion is positive and for the other emotions is negative. When an avatar has assessed the emotional influence, the emotional and mood state are updated in two steps. The first step consists in updating the emotional state. The second step consists of updating the mood state. The emotional state is updated taking into account the last mood state as follows:

$$e_{t+1} = e_t + \Psi_e(p, \sigma_t, a) + \Omega_e(p, \omega_t, \sigma_t) \quad (5)$$

We define a 6×5 *Personality-Emotion Influence Matrix* P_0 (how each personality factor influences each emotion). This matrix is defined once and it is multiplied with the vector p to obtain a new vector u. We use this new vector to construct a diagonal matrix P (how strong an emotion can be given the personality). Thus, we compute a 6×3 *Mood-Emotion Influence Matrix* T (how mood influences emotion) that is multiplied with the current mood m_t to obtain the influence of mood on the final emotional state. Therefore, we obtain the following definition for the function Ψ_e:

$$\Psi_e(p, \sigma_t, a) = P \cdot a + T \cdot m_t \quad (6)$$

Finally, the function for the emotional regulation Ω_e is defined as a 6-dimensional vector. This vector contains the amount of decrement or increment desired for each of the six emotions of an avatar. We apply the defined rules in the previous section. In our case for all the possible outcomes, the desired increase for each possible emotion is normally 0.03 and for the other emotions the desired decay is -0.03. The mood state is updated by a function that calculates the mood change based on the new emotional state:

$$m_{t+1} = m_t + \Psi_m(p, \omega_{t+1}, \sigma_t, a) + \Omega_m(p, \omega_{t+1}, \sigma_t) \quad (7)$$

We use a 3×6 *Emotion-Mood Influence Matrix* Q that defines the relation between the emotions and each mood dimension. The influence of vector a on the mood is calculated by $Q \times a$. Similarly to the emotion update using the personality, we now also define a 3×5 *Personality-Mood Influence Matrix* R_0 (how each personality factor influences each mood dimension). This matrix is also defined once and it is multiplied with the vector p to obtain a new vector v. We use this new vector to construct a diagonal matrix R. Thus, we obtain the following definition for the function Ψ_m:

$$\Psi_m(p, \sigma_t, a) = R \cdot Q \cdot a \quad (8)$$

Finally, the function for the mood regulation Ω_m is defined as a 3-dimensional vector. This vector contains the contains the amount of decrement or increment desired for each of the

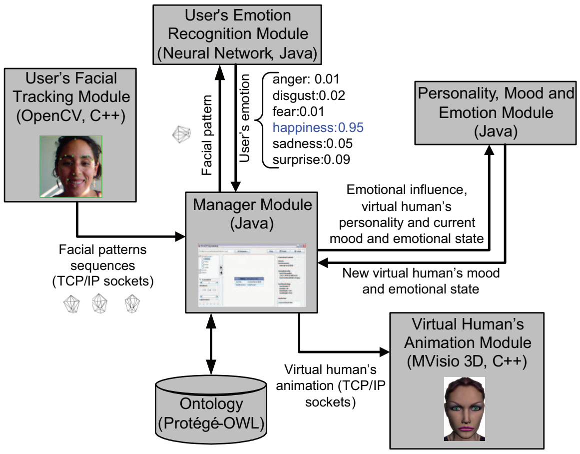

Figure 2. Architecture for Empathic Reactions of an Avatar toward a User in a HCI Scenario

three moods of an avatar. We apply the defined rules in the previous section. In our case, for all the possible outcomes, the desired values normally are 0.03 for the good value, 0.1 for the neutral value and -0.3 for the bad value. In another case the desired values normally are -0.03 for the good value, 0.1 for the neutral value, and 0.3 for the bad value.

IV. System Implementation

As depicted in figure 2, we have implemented a system for simulating empathic reactions of virtual humans in a HCI scenario. This simulation is based on the EI model described in previous section.

The developed system has the following functioning: the *Manager Module* receives facial patterns from the *User's Facial Tracking Module* and sends these to the *User's Emotion Recognition Module*. We consider 13 facial feature points as reference points to create a robust tracking of the facial expressions of a user as presented in [19]. These points are located on the following facial areas of user: forehead (one point), right eyebrow (three points), left eyebrow (three points), right nostril (one point), left nostril (one points) and mouth (four points). To implement this module, we have trained an artificial neural network based on well-known backpropagation algorithm [20] using a set of images obtained from three different image databases [23] [22] [21], where different persons are expressing the six basic emotions. Some samples of the training images and their corresponding facial patterns are presented in figure 3. Later, the Manager Module receives from the *User's Emotion Recognition Module* the recognized emotion of user emotion and sends this together with the self-knowledge of virtual human to the *Avatar's Personality, Mood and Emotion Module*. After this, the Manager Module receives from the *Avatar's Personality, Mood and Emotion Module* the new configuration of the affective state of virtual human to choose an appropriate facial animation sequence to be performed, and finally, the Manager Module sends this animation sequence to the *Avatars's Animation Module*, which reproduces it. Figure 4 shows some resulting screen shots of the different emotions

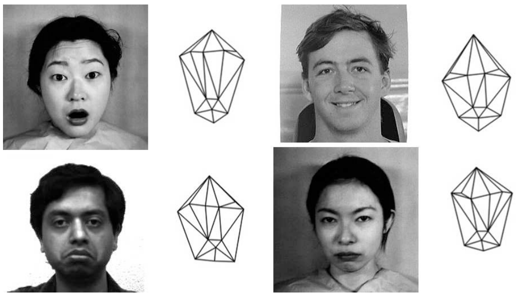

Figure 3. Some Training Images (left) and their Corresponding Facial Patterns (right)

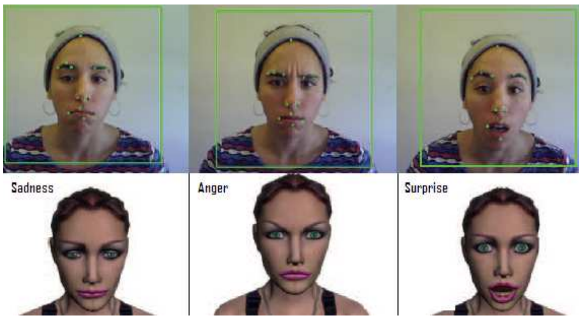

Figure 4. Some Facial Expressions of a User and the Corresponding Empathic Reactions of an Avatar in a HCI Scenario

expressed by a user and the corresponding empathic reactions of a virtual human in a real-time HCI scenario.

V. Conclusions

In this paper, we have presented a different approach to model EI in virtual humans in order to create empathic characters. This model uses the ECF defined in the EI model, which defines three human competencies: self-consciousness, social awareness and self-regulation. An important consideration for the future is the evaluation of the system with several users, and the implementation of a self evaluation process (learning) inside the avatar in order that it becomes able to generate more adequate responses. Thus, the avatar can learn to adopt a specific self-regulation treatment for a specific behavior in a particular situation. Other perspective for the future of this work is to implement other communication modalities for virtual humans, this means to include body gestures, audio sequences and text sequences to create a better and complete mechanism of empathic reactions of virtual humans in more complex HCI scenarios.

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