A Model for an Emotional Respondent Robot

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Abstract. The aim of this study is to design an emotional regulation model based on facial expressions. It is argued that emotions serve a critical function in intelligent behavior and some researchers posed the questions of whether a robot could be intelligent without emotions. As a result, emotion recognition and adequate reaction are essential requirements for enhancing the quality of human robot interaction. This study proposes a computational model of emotion capable of clustering the perceived facial expression, and using cognitive reappraisal to switch its internal state so as to give a human-like reaction over the time. That is, the agent learns the person's facial expression by using Self Organizing Map, and gives it a meaning by mapping the perceived expression into its internal state diagram. As a result, the presented model implements empathy with the aim to enhance human-robot communication.

1 Introduction

Intelligent agent start having a close touch with all walks of life with important applications in several fields such as gaming, advertisement, health and personal assistance.

Focusing on the health field, researches support the idea of a robotic assistant for children with autism by longitudinal research [1, 2]; also, service robots could be beneficial in retirement houses to give various health care for elderly people [3]. Since this kind of interactions require good communication, there is the need to increase emotional and cognitive abilities of agents. We conjecture that empathy is one of the key issues affecting the quality of interaction, and we focus on the study of automatic facial expressions, which gives important cue for assessing the (human) partner's emotional state, and on the implementation of a communication model, which enable the robot to associate facial expressions to its internal states (embodiments of emotions). Having strengthened those connections, the robot will be able to understand the partner's emotion, to synchronize its internal state to the one of the human partner, and to move to the most suitable next emotional state. In other words, the aim of this study is to model a coherent course of emotions over the time.

Several architectures have been proposed for artificial emotions and some of the models are equipped with animated face and body. While some models focus on

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mechanical engineering with aim to mimic the input facial expression back to the spectator, others try to implement a model to control the emotional states of the humanoid robots.

In 2003, Breazeal [4] presented the emotional model of the animated face KISMET. The top-level goal of the agent is to satisfy its three drives, the social, the stimulation and the fatigue ones, by bringing them to their homeostatic regimes. The drives and the external stimulus sensed by KISMET affect its current set of beliefs, which are then mapped into a 3D (arousal, valence, stance) affective space to produce an emotion. The trigged emotion is finally displayed by the motor and the behavior systems.

In 2003, Arkin et al. [5] introduced the AIBO dog and the SDR humanoid robots. Both agents are equipped with a 3D mental model of emotions having activation, pleasantness and certainty dimensions and an ethological model which provides a basis for behavior selection.

In 2004, J. Gratch and S. Marcella [7] presented their computational model of emotion, EMA, based on the appraisal theory. EMA keeps an explicit representation of the agent-environment relationship, called 'causal interpretation', which consists of a snapshot of the agent's current knowledge. External stimulus as well as agent's behavior change this knowledge over the time. During the 'appraisal derivation' stage all significant features of the causal interpretation are represented into a data structure, or 'appraisal frame', which are passed to the 'emotion derivation' model to produce an emotional response, the agent's coping strategy. The triggered emotional response is biased by an overall mood state.

In 2004, Miwa et al. [8] developed the WE-4R human-like robot capable of communicate naturally with human by expressing human-like emotions.

In 2007, Esau et al. [6] introduced the robot head MEXI, which uses artificial emotions and drives to control its behavior. MEXI considers the four basic emotions of anger, happiness, sadness and fear.

In 2007 Hirth et al. [9] presented a behavior based emotional control architectures for the robot head ROMAN.

In 2007, Watanabe et al. [10] proposed an agent which learns to link the expression of the human partner with its own internal state via intuitive parenting.

In 2009, Hasimoto et al. [11] developed a head robot called KAMIN to enhance human-robot communication. The analysis of the human voice allows KAMIN to recognize the human emotion, which is then mapped into the Russell's circumflex 2D model. The emotional generation space of KAMIN realizes the entrainment between the human and the robotic emotion.

In 2014, Angelica Lim and Hiroshi G. Okuno [12] presented their computational model of emotion based on the field of developmental robotics [13]. The main assumption is that emotions are not built-in, but they can be learned by any learning entity (a child or a robot), when it receives the correct stimuli. The emotion developmental system designed in this paper is implemented into the Multimodal Emotional Intelligence (MEI) robot.

Although several computational models of emotions have been proposed before, there is still the need to investigate on this issue and to create alternative architectures, which can also be used to investigate psychological theories.

This paper proposes a new emotional respondent robot, which can regulate itself regarding the flow of the dialog with a human partner, by reading user's facial expression and using cognitive reappraisal to switch to its next artificial internal state; at the end of each episode the agent acknowledges the human's current emotional state and its affective state. The main contribution of this work is to increase the quality of human-robot interaction by adding empathy to our computational model of emotion.

Section 2 gives an overview of the current theories of emotions; Sect. 3 introduces the proposed system with implementation details. Section 4, presents our experimental setup and results. Lastly, interpretation of the results and future works are in Sect. 5.

2 Background for Theory of Emotion

Minimally, a psychological theory of emotion explains the cognitive and social emotional sphere of human being. The presence of several psychological theories of emotions complicates further its implementation, but it adds also value to it, since a computational model can be used to validate the corresponding theory.

Currently, the main three theories of emotions are:

Discrete Theories
They assert that there is a limited number of core emotions and their expressions is shared across people and culture [14]; these emotions are happiness, sadness, surprise, fear, anger and disgust. Each basic emotion serves to prepare and motivate the reaction to a particular context. Moreover, emotions allow to learn new behavior, and they are also refined throughout emotional development. The main criticism to these theory is that it fails to describe the complexity of the emotional space.

Dimensional Theories
Emotions are mapped into 2D and 3D emotional space. Computational models of 3D based on these theories often use the PAD emotional space of Mehrabian and Russell [15], where the three dimensions corresponds to Pleasure (amount of pleasantness i.e. liking versus disliking), Arousal (amount of mental alertness and physical activation, it describes how excited or apathetic is the emotion i.e. sleepiness of boredom versus exciting), and Dominance (a measure of power or control versus submissiveness i.e. anger, boldness, and relaxation versus fear, anxiety and loneliness).

Appraisal Theories
These theories assert that emotions reflect the personal-environment relationships; that is, emotions arise from the process of comparing individual internal needs to the external demands. The result of this evaluation is mapped into a set of appraisal variables that produce an emotional response [16]. Furthermore, in 1991, Lazarus [17] details how the trigged emotion leads to coping responses, which can be "problem-directed", when they aim to change the environment, or "emotion-directed", when they aim to modulate the trigged emotion. This process of emotion stabilization is called behavioral homeostasis [18]. The major criticisms to these theories argue that emotions are mainly reactive, and appraisal can be considered as a consequent, not a precedent of the emotional reaction. Moreover, humans experience 'feelings', and

mood, as well as personality affect the trigged emotion. That is, appraisal rules are insufficient to explain all the complexity of the emotional reaction.

3 Design of the Proposed Model

3.1 Overview

The virtual agent introduces in this paper monitors the user by looking at him-her, and recognizing his-her mimics, as depicted in Fig. 1. Moreover, it gives meaning to the user's expression via mapping it into its internal state diagram; which is designed regarding the three dimensions of pleasure, arousal and dominance axes [19]. After the observation, the agent regulates its affect state dynamically considering the user's facial signals and its current state. In positive and negative circumstances, the agent uses cognitive reappraisal to keep away itself from a high level emotional moods and keep itself in more positive emotion. Cognitive reappraisal allows the agent to change its current state considering its internal and desired states. At the end of the regulation process, the agent gives a statement about its new emotional state. That is, the output of one regulation phase depends on three matters:

1. Which affect state the agent is in
2. What is the message of the user's expression
3. The values of α and β used in Eq. (1)

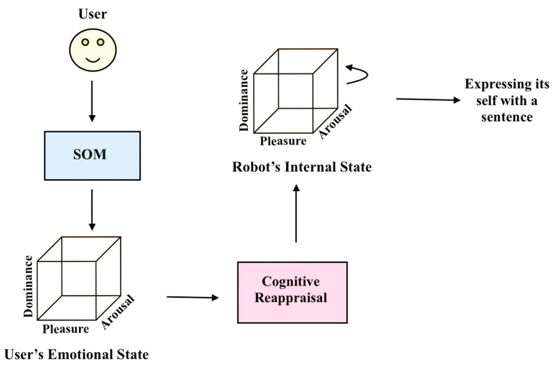

Fig. 1. Regulation steps of the agent's internal state in a dialog with a user regarding facial expressions

3.2 Cognitive Reappraisal

People use emotional regulation strategies consciously or nonconsciously, when they have too high or too low emotional state. A purpose of it is to make changes on their emotional response. One of these strategies is cognitive reappraisal and it brings about changing on focused other potential aspect of the circumstances. In other words, reappraisal shrinks the possible emotional effect of circumstance.

For instance, a student who did not study enough for her/his exam blames her/his teacher to ask too hard questions [20, 21].

There are more four different emotional regulation strategies which are situation selection, situation modification, attentional deployment and response suppression. Each strategy focuses on a different element to change. Through the studies, cognitive reappraisal and response suppression were found two most effective strategies. Furthermore, using cognitive reappraisal has more positive effect on socialization, since it does not cause to hide negative or positive social clues and also it affects both emotional reaction and experience [21]. Therefore, in this paper cognitive reappraisal is considered.

In this model, the agent adjusts the effect of internal and external perception by decreasing its impact. After regulated its effect, new values of the perceived emotional state are considered as desired state. Cognitive reappraisal affects in different level positive and negative situations. If the current recognized state is a negative emotion, intensity of the emotion decreases at rate of one quarter of it. On the other hand, when the current state is a positive emotion, this percentage is ten percent of the emotion. By this way, the desired emotional situation is obtained as more positive than the perceived negative situation. The virtual agent's response is determined regarding its current internal state and the next desired state. In this way, the agent reacts suitable for also its current internal state. Equation (1) shows how the virtual agent responses with cognitive reappraisal:

$$internal\_s_{t+1} = \beta * internal\_s_t + \alpha * desired\_s_t \tag{1}$$

Where both β and α are constant values; they determine the ratio of the components of the new emotional state. For instance, if α is 1.0 and β is 0, the agent generates its next affect state in the direction of the emotion which comes from the user.

3.3 Internal State Diagram

The internal state of the agents is designed regarding to computational models of emotion. Most convenient theory is Russell and Mehrabian three-dimensional affect model to represent an internal state. The three-dimensional model is an extension of an two dimension one, where the dominance dimension is added to arousal and pleasure axes (PAD), see Fig. 2 [22], since only two axes are not enough to discriminate all affects. For example, even anger and fear have completely different behavior tendencies and facial expressions, both are on the top left corner on the two-dimensional psychological judgement space which are high arousal and displeasure [23].

In our study, emotions which have dominance value greater than zero were combined on the same surface of internal state, while emotions with dominance value smaller than 0 were mapped into another surface of internal state.

Our synthetic internal state model contains three levels of fear, anger, happiness, sadness emotions and a natural state. Anger and happiness are on the first level of the diagram dominance greater than zero and fear and sadness are on the second level dominance smaller than zero. Besides, both surface involves natural state. Levels of diagram are designed as indicated in Fig. 3:

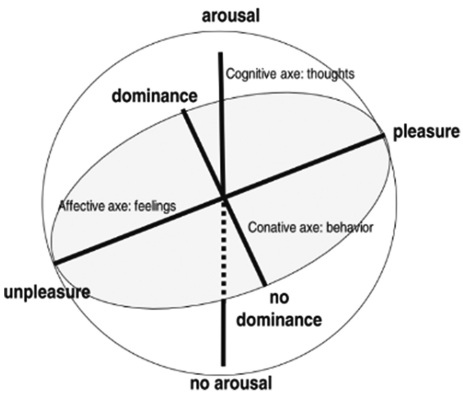

Fig. 2. Diagram of theory of PAD [15]

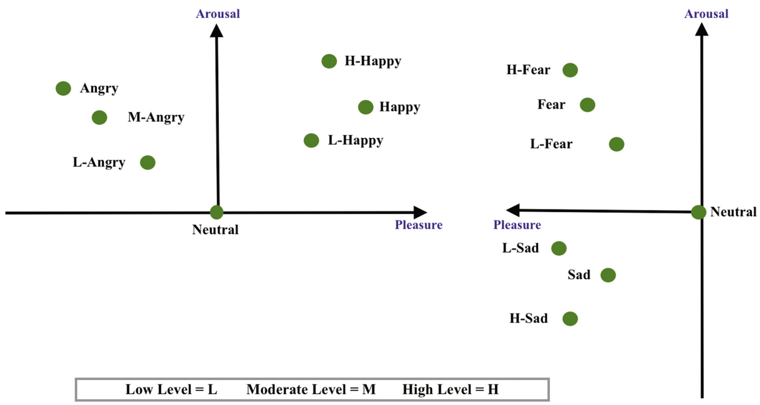

Fig. 3. Internal space of the agent in two surface

To fix the position of every emotions, studies of Mehrabian and Russell [19] and Plutchik [25] are considered. Plutchik had study on semantic and intensity analysis between wide range of emotions; thanks to this research, positions of levels of the four emotions are identified depending on other similar emotions. For example, Plutchik's theory shows that hostility and annoyance are in the similar direction with anger but hostility is lighter than anger and same relationship is valid for annoyance and hostility, annoyance have lower intensity than hostility. In this paper, positions of hostility and annoyance which are obtained from studies of Mehrabian and Russel uses as moderate and low levels of the anger.

3.4 Facial Expression Recognition

The Self Organizing Map (SOM) is used to teach facial expression recognition and the Extended Cohn Kanade Database (CK+) is utilized as training data. The database contains anger (45 faces), contempt (18 faces), disgust (59 faces), fear (24 faces), happiness (69 faces), sadness (28 faces) and surprise (83 faces) emotions. Participants of the database are 210 adults which are ages between 18 and 50 and %67 participants are female. Distribution of participants' ethnic background is %81 Euro-American, % 13 Afro-American and %6 other groups. Participants got training to perform by an experimenter. Each presentation of emotion starts and ends with a neutral pose. From each presentation, picked facial expression is used on the training phase [26].

At first step, four basic emotions of angry, happiness, sadness and fear which are used in the internal states diagram of Fig. 3 and natural poses are chosen and converted to gray scaled images. After face components are detected and cropped as shown in the Fig. 4, images normalized by histogram equalization.

At the second step, vectorized images are given to the SOM to build a map to read the users' facial expressions. We controlled the construction of SOM with the aim to build a 3D clustering space resembling the internal state diagram of Fig. 5: that is, just before the iterative training phase, images which represent the mean for specific category of emotions are assigned at the center positions of each emotion cluster. By doing like that, the resulting SOM (Fig. 7) has a 1-to-1 mapping with the 3D PAD space of Fig. 3 and this gives an opportunity to interpret the emotional state of the user regarding to the internal state diagram of Fig. 3 with the position of the winning node of the emotion reading. That is, the size of the constructed SOM is $8 \times 8 \times 2$ corresponding to 128 emotional states.

Fig. 4. From left to right: A test image with its face landmarks, the cropped mouth

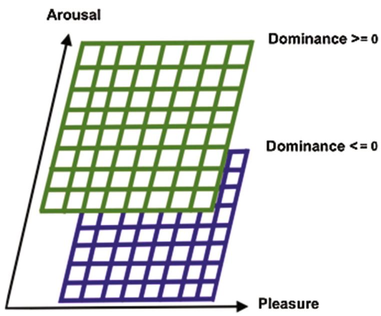

Fig. 5. A representation of the three dimensional emotion clustering

4 Experiment

4.1 Experimental Setup

In the experiment, four states of emotion (happiness, anger, fear and sadness) and natural state are used with three different subject (see Fig. 6). All test images are taken by a camera of the computer in natural environments. Images are presented to the agent in a random way.

At each episode, the agent witnesses the user's facial expression via an image. After the recognition, the user's state of the affect is read on the pleasure – arousal – dominance axes and the rates of dimensions are evaluated regarding the internal state diagram. At the cognitive reappraisal phase, intensity of the current emotional state decreases in specific ratio regarding being negative emotion or not. When re-generating the internal state, seventy percent of the current state of the virtual agent is taken as basis, so the desired situation has an impact on thirty percent of the next state. At the end of each episode, the agent tells how it sees the user and how it feels. Episodes are done consecutively, thus the agent uses the regulated internal state of the previous episode as initial state. Only in the first episode, the agent's initial state is assigned as random inside the pool of natural state.

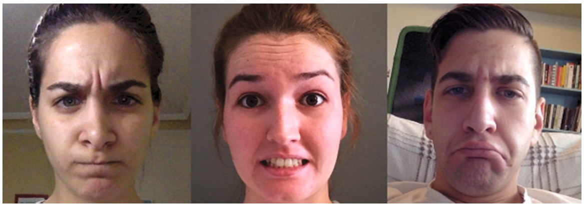

Fig. 6. Example of the users' images. From left to right: subject 1 acting 'angry', subject 2 acting 'fear', and subject 3 acting 'sad'

4.2 Results of Emotion Recognition

According to the PAD rate of the emotional states [10], the ideal clustering map is designed for the five categories of facial expression and they are clustered successfully respecting the ideal map, as shown in Fig. 7. Rows of the maps is representing the pleasure axis, and columns of the maps is representing the arousal axis, the dominance dimension originates the two planes. The central point of the pleasure and arousal axis is between fourth and fifth elements of the 3D SOM. Besides, at each training session, the positions of the clusters do not change due to the control on the map. We worked with the block of the mouth (which is cropped as shown in Fig. 4) since it gave better results than whole face and the block of the eyes. The recognition is done with nearest neighbor.

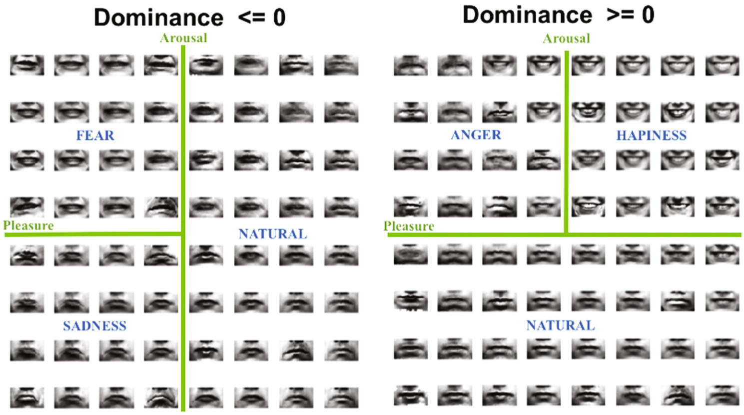

Fig. 7. Output of the self organizing map

4.3 Results of Emotion Regulation

Some examples of the possible episodes are below: the agent acknowledges the current emotional state of the human partner and moves to a suitable internal state. Looking at the first three episodes, we can see that the agent successfully acknowledges the perceived emotional state of the human partner, and empathizes with him-her by switching to a nearby emotional state. In episode four, we can see that the agent struggled to adapt itself to big changes in mood of conversation. That is, the agent gets confused on changing its emotional condition from medium angry to happy. However, except for large transitions, the effect of cognitive reappraisal can be observed more clearly on the rest of the dialog.

Episode 1:
As I see, you feel little sad.
I feel little sad.
Episode 2:
As I see, you feel neutral.
I feel neutral but close to happy.
Episode 3:
As I see, you feel angry.
I feel medium angry.
Episode 4:
As I see, you feel very happy.
I feel angry.

5 Conclusion

In this paper, a design of a respondent emotional robot is presented, also cognitive reappraisal and three-dimensional emotion theory are considered and discussed. The internal state diagram is designed to interpret a user's facial expression and to change the robot's internal state dynamically regarding the flow of conversation. The results are showed that three-dimensional theory is successful to represent the agent's internal state and understand emotional state of a person. Generally, the agent responds properly regarding its current state and external circumstance, except when high volume alterations on the external condition occurs. We believe that this result is consistent to human beings, since people can live more or less the same struggle to jump from a negative situation to a positive one. Future work includes further experiments and discussions as well as quantitative and qualitative evaluation of the respondent robot.

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