A Possibility for Expressing Multi-Emotion on Robot Faces

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Abstract

Human has been well known for having complicated emotion. Unfortunately, we have so far little knowledge to understand hidden mechanisms for generating such emotion. Most of the time, without meditation and mind focus, human could have more than one emotion simultaneously. Yet, in the area mind tranquilization, practitioners have learnt that feeling and emotion are serial, not parallel processes. Multiple emotions happen consecutively back and forth. When absent minded, human could not differentiate each emotion and behave as if several emotions are being superimposed. Devising technique to artificially superimpose emotion on robot's faces may help us partially understand the response on human face while having multiple emotions. At least, the result will initiate a novel way for robots to express several emotions simultaneously. We perform our initial study and trial on a face robot toy, called Yano. This is to minimize our effort, spent for designing mechanisms of face robot. Although Yano has a limited degree of freedom, we have studied a possibility of superimposition of emotion on robotic faces. Subsequently, we define a minimum set of actuators representing basic emotions which will be required on our robot's face. Finally, GUI, based on such a set of actuators is shown and the results was discussed herein

Keywords: face robot, superimposition of emotion and facial expression

1. Literature Review

Many past attempts were carried out to come up with several methods in order to measure human facial expression. Duchenne (1862) [1] was the first anatomist interested in how the facial muscles work. He electrically stimulated facial muscle to change appearances of a face. However, human muscles apparently lie over the others. Therefore, its stiffness and clamping are highly coupled. Some muscles then could not be stimulated and/or activated separately. Subsequently, Ekman and Friesen (1978) studied and developed a system called "Facial Action Coding System (FACS)" [2]. They observed some visible facial muscles and named it "action units (AUs)". An action unit may contain more than one muscle such as "brow lowerer" which causes three muscles working together. These muscles are technically named based on its locations: Depressor Glabellae, Depressor Supercilii and Corrugator Supercilii.

Figure 1. ReplieeQ2 [3]

At present, facial expression emerges as an important trend in engineering because of the immense interest of human-robot interaction. The field of human-robot interaction explains interacting mechanisms between human and robots. All predictions to date lead to the greatly increase number of intelligent robots in various application. Most of them will be working closely to human. It is then compulsory that robots must understand both human verbal and nonverbal languages. On the same token, robot's response must be as well understandable. In human, facial expression is the important factor supporting verbal and nonverbal interaction resulting in smooth, good performance interaction. Introducing facial expression to the field of robotic will be a key to a success human-robot interaction.

There are many face robots, built as similar and not similar to human. Some are quite noble: "ReplieeQ2" and "Kismet". The most human-like prototype is ReplieeQ2, shown in Figure 1, developed by Professor Hiroshi Ishiguro of Osaka University [3]. ReplieeQ1 is a female robot. She could perform several simple interactions such as speaking and facial expressions, similar to human. Its mechanic system for soft and smooth motion benefits from pneumatic actuators. Such design also avoids heat problem and mechanical noises, while requires less area for installation of these devices. Her realistic skin is composed from silicone.

Another prototype of face robots was developed based on emotion-principle framework, called Kismet [4]. This robot is a part of work by Cynthia L. Breazeal at MIT in late 1990s. It is a creature-like face robot. It has auditory, visual and facial expression systems for interacting with human. Breazeal introduced 3D orthogonal space of emotion framework, consisting of Arousal, Valence and Stance. The 3D space (See Fig 2) could also resolve problems of same parameters in the 2D space: Arousal and Valence such as Fear and Anger. Kismet has a function to calculate emotion parameters of Arousal, Valence and Stance from values fed to its sensors. Consequently Kismet was claimed to perform proper facial expressions during its interaction with human.

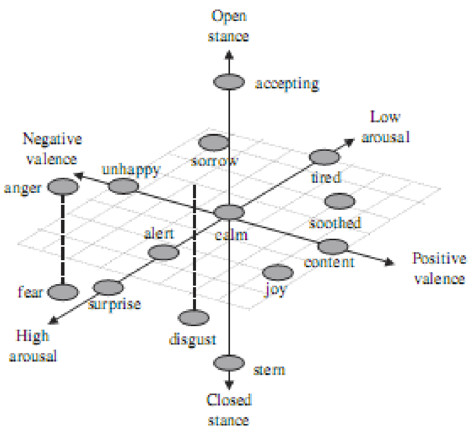

Figure 2. 3D Space emotion by Cynthia Breazeal[4]

2. Introduction

We argue that emotions have influence towards facial expression while types of mapping or transformation are not yet precisely known. More understanding of such a process will enable successful interaction between robot and human. Some research works aimed at exploring superimposition mechanisms of several emotions onto facial expression of robots. Arya et al. [5] studied a relation between perception of facial expressions and character-based applications. The initial results showed that there was no one-to-one mapping between them. Paradiso [6] derived an algebraic equation for facial expressions, attempting to formulate a computing framework deployed into computers. Our research, however, is based on an assumption that emotion on robot faces could be artificially computed although there are presently no mathematical tools to do so. We attempt to simplify a way to superimpose emotions, to be expressed on robot faces. We begin our work by identifying each muscle moving unit of the faces, suitable expressing robot's artificial emotions. Then, we apply simple linear combinations with pre-computed weighting factors for sensitivity enhancement. We believe that this sensitivity highly varies among cultures of each human race. Therefore, values of weighting factors are tacit knowledge based. With reasonable amount of real world data and effective trained algorithm, ones could achieve the right sensitivity. We exclude this aspect out of our work for the time being. However, we perform our research within the cultural environment of Thailand and all human, providing sample data are Thai. Consequently, the experiment results, presented in this paper is bounded and limited to the generality of Thai people.

Table 1. Mapping facial movement into emotions

	Raise Eyebrow	Lower Eyebrow	Raise Eyelid	Raise Cheek	Lower Cheek	Open Mouth
Happiness			X	X		X
Surprise	X		X			X
Anger		X	X			
Disgust		X	X	X		
Fear	X		X			X
Sadness		X			X	

3. First attempt with Yano

To achieve the best performance of face robots, we inevitably require knowledge and understanding of basic emotions expression. For quick verification, we use Yano as a prototype. Yano is a "male" toy robot which can display "emotional" information through its facial expression, together with hands moving. It has five facial basic features consists of eyebrows, eyelids, ears, cheeks and mouth. These are moving facial features by three coupling DC motors. The eyebrows, eyelids and ears are driven by a single motor through tracks and wheels. This is, of course, contradict to the case of some people who can move their eyebrows, independent of eyelids. The other two DC motors in Yano are driven for cheeks and mouth.

Our goal is to command Yano to express these basic features, leading to basic emotions. We have modified mechanism of Yano and insert four servo motors. The Arduino ATmega 1280 controller is used to command those motors. With these arrangement, Yano could express six basic emotions on his face i.e. happiness, surprise, anger, disgust, fear and sadness. Note that these expressions, as mentioned earlier, are configured with Thai cultural understanding. We make no claim that these face configurations are universal. A table 1, mapping facial muscles to facial expressions, was created as shown, using concept proposed by Breazeal [4]. Breazeal also adapted this table from Smith & Scott [7] and implemented with her robot, Kismet at MIT.

Smith & Scott mapped facial movement to affective dimensions. Using up and down arrows to indicate the increasing and decreasing levels of the affect meaning dimension. Unlike Kismet, Yano has limited degrees of freedom for mapping facial muscles to facial expression. We simplified and modified a possible mapping according to the actuators of Yano, shown in table 1. Some emotions were adjusted. The results are shown in Figure 3. This figure shows that disgust and fear are hardly distinguished due to lacking degrees of freedom of Yano. We suggest that disgust should raise the upper lip a bit more.

It is ironic to witness that commanding robots to express emotions is much easier and simpler than commanding human, even ourselves. In case of robots, we could command positions of servos directly from computer but in human there are many factors uncontrollable. The mapping processes of emotional expression between robots and human could be either similar or different. The state of the art in robotics and neurology is still far below a level of understanding towards this complexity.

Figure 3. Yano's expression of basic emotion

We collect data from 15 people who were observing the facial expression of Yano. There are six basic emotional expressions by Yano, consisting of anger, disgust, fear, happiness, sadness and surprise. Table 2 shows that fear, surprise and sadness could be recognized correctly. People are apparently confused with anger and disgust. Note that, in the Table 2, A = Anger, D = Disgust, F = Fear, H = Happiness, Sa = Sadness and Su = Surprise.

Table 2. Identification of Yano's emotion expression

Yano's Emotion	Emotions are recognized by subjects					
	A	D	F	H	Sa	Su
A	5	4	4	1	1	0
D	8	4	1	0	0	1
F	1	6	8	0	1	0
H	0	0	0	13	0	3
Sa	0	0	0	0	13	0
Su	1	1	2	1	0	11

4. Identification of a minimum set of actuators representing basic emotions

Human face has many degrees of freedom. If we were to build a complete match with natural organs, we would need many actuators, representing action units. However, the mapping between actuators and muscle need not to be one to one. In this section, we identify a minimum number of muscles that could represent basic emotions. Each emotion must be clearly distinguished and independent from others since the results of superimposition will be meaningful and understandable. Figure 4 shows the position of actuators necessary to express each emotion. With this information, we devised table 3 to represent a minimum set of actuators and table 4 to couple actuators for basic emotions.

Figure 4. The position of actuators in each emotion and result of facial expression by them is showed.

Table 3. A minimum set of actuators required to express basic features corresponding to its name and action units from FACS.

Motor	Facial action	Action Units
M1	Left Eyebrow Frown	AU4
M2	Right Eyebrow Frown	AU4
M3	Left Inner Eyebrow Raise	AU1
M4	Right Inner Eyebrow Raise	AU1
M5	Left Outer Eyebrow Raise	AU2
M6	Right Outer Eyebrow Raise	AU2
M7	Raise Left Upper Eyelid	AU5
M8	Raise Right Upper Eyelid	AU5
M9	Raise Left Cheek	AU6
M10	Raise Right Cheek	AU6
M11	Nose Wrinkle	AU9
M12	Raise Left Lip Corner	AU12
M13	Raise Central Upper Lip	AU10
M14	Raise Right Lip Corner	AU12
M15	Left Lip Stretcher	AU20
M16	Right Lip Stretcher	AU20
M17	Left Lip Corner Depress	AU15
M18	Right Lip Corner Depress	AU15
M19	Open Mouth	AU26

Table 4. A combinations of actuators in table 3 to generate basic emotions are showed.

Emotion	Combination of Motors
Anger	M1,M2,M7,M8
Disgust	M1,M2,M11,M13
Fear	M1,M2,M3,M4,M5,M6,M7,M8,M15,M16
Happiness	M7,M8,M12,M14
Sadness	M1,M2,M3,M4,M17,M18
Surprise	M3,M4,M5,M6,M7,M8,M19

5. Linear combination of emotion

We have created a GUI to simulate the superimposition of emotion (E_i) between two faces. The user could select each face's emotion and its weight. Both faces are superimposed by linear combination (E_{sum}). W_i are weighting factors:

$$E_{sum} = W_1 * E_1 + W_2 * E_2 \quad (1)$$

The plus sign is an average sum of position of actuator in face 1 and face 2.

Figure 5 shows results of the superimposition of emotions by average sum method. Many results conform to natural feeling of observers. Some are conflicting though. Each individual has different facial expression because of parental nurture and culture. The conflicting space is wide which applied to groups of various cultures.

6. Conclusion

Our GUI was designed based on a minimum set of actuators. More actuators will certainly yield better results, but difficult to be implemented for real robots as found in Yano. The experimental results with Yano and simulation outputs of our GUI are giving us a starting step for designing a human-like face robot.

The linear combination of emotions leads some unfavorable results in some unnatural faces. It somehow enables belief that emotional combining processes are probably of nonlinear types. Furthermore, a notion of how people interpret emotions is yet unknown. Each people express their emotions in different ways, based on some unknown and uncontrollable parameters. Given that we succeed to know all parameters involved, we still encounter with complex relationship among them. Such complexity may be immensely greater than computational powers of artificial intelligent systems. However, it is worth for us, in the next step, to make attempts to deploy some concepts of AI to identify what processes could capture such emotional complexity.

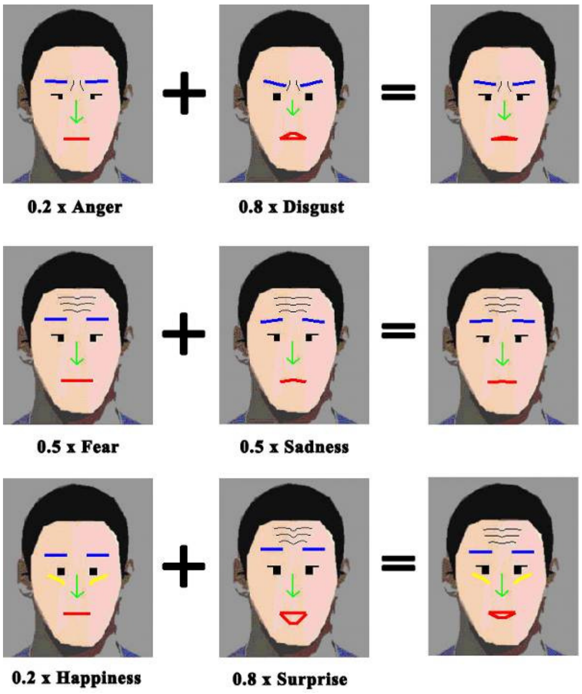

Figure 5. Superimposition of emotions

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