A Robot Simulator ‘FRESi’ for Dynamic Facial Expression

Jeong Woo Park*     Won Hwa Kim**     Won Hyung Lee***     Myung Jin Chung+

KAIST
(pjw*, wonhwaya**, leestation***)@rrlab.kaist.ac.kr, +mjchung@ee.kaist.ac.kr

Abstract - Most of the robots are nowadays evolving and imitating human social skills to achieve sociable interaction with humans. Socially interactive robots require different characteristics rather than conventional robots. Likewise human-human interaction, human-robot interaction is also accompanied with emotional interaction. Therefore, the robot's emotional expression is very important for human, especially facial expressions play an important role among the whole part of the human body.

In this paper, we introduce a facial robot expression simulator ‘FRESi’.

Keywords - Human-robot interaction, facial expression, FRESi.

1. Introduction

Nowadays various types of robots are developed. Among these robots, a common characteristic of the so-called socially interactive robot is to interact with humans. Socially interactive robots, such as service robots, entertainment robots, and education robots, generally give information and amenities to humans by interacting with them. While humans interact with robots, they want the robots to behave similar to the humans do.

In HHI(Human Human Interaction), humans exchange information or emotional states with others using various methods such as languages, gestures, facial expressions and etc. According to Mehrabian, the words account for 7% of liking, the tone of voice accounts for 38%, and the body language accounts for 55%[1]. Among the forms of body language, facial expression and gestures occupy a major component. Hence, research on implementing facial expression and gestures is important to express human’s emotional state [2].

So far, many robots have been developed with a focus on HRI [3-7], specifically on facial expressions, because the face is the most effective part of the human body to express the emotional states.

However, most of the results in the previous researches have some common features that are different from human facial expressions. First, they have static emotional expressions: There is no movement in their expression after arriving at the target positions. Human’s facial expression is not static but varies dynamically when it expresses the emotional states. Moreover, facial muscles do not stay on one target position. We can easily see it on dramas or movies. Second, they have time-invariant facial expressions: They always show the same facial expression for the same emotional state in a different time.

2. Dynamic Facial Expression Based on LDAEM

In this section, we describe a method by which dynamic robot facial expressions based on LDAEM(Linear Dynamic Affect Expression Model) [8, 9].

In LDAEM, robot’s emotional states are determined by equation (1) [8, 9]. Here, e represents the emotion vector which is determined through external stimuli s.

\[
M\hat{e} + C\hat{e} + Ke = s
\]

\[
e \triangleq \begin{bmatrix} e_1, e_2, \ldots, e_9 \end{bmatrix}^T, s \triangleq \begin{bmatrix} s_1, s_2, \ldots, s_9 \end{bmatrix}^T
\]

\[
M \triangleq \begin{bmatrix} m_{11} & 0 & \cdots & 0 \\ 0 & m_{22} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & m_{99} \end{bmatrix}, C \triangleq \begin{bmatrix} c_1, 0, \ldots, 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0, 0, \ldots, c_9 \end{bmatrix}, K \triangleq \begin{bmatrix} k_1, k_2, \ldots, k_9 \end{bmatrix}
\]

Then, robot’s expression is decided by transition matrix \( T_f \) in equation (2) [8, 9].

\[
T_f = T_{(D_2, D_1)} T_{(D_2, D_1)}, T_{(D_2, D_1)} = T_{(D_2, D_1)} T_{(D_1, D_2)}
\]

\[
p = \begin{bmatrix} a_1, a_2, \ldots, a_{D_2} \end{bmatrix}^T
\]

\[
a_i : normalized value of control point
\]

\[
T_f : transition matrix between affect and expression space
\]

At this time, we add random variation to each basis as in equation (3). Here, we define a new variable \( \tilde{e} \) to represent random-varied emotions.

\[
\tilde{e} = \begin{bmatrix} \tilde{e}_1, \tilde{e}_2, \ldots, \tilde{e}_9 \end{bmatrix}^T = \begin{bmatrix} \hat{e} + e_{1} \cdot n_1, e_2 \cdot n_2, \ldots, e_9 \cdot n_9 \end{bmatrix}^T, \| \tilde{e} - e \| \leq b_i
\]

\[
n_j = \frac{\text{rand}() - b_j}{v_j}, -1 < \text{rand}() < 1,
\]

\[
e : current emotion vector
\]

\[
e_i : target emotion vector for i-th emotion
\]

\[
\tilde{e} : newly generated emotion vector
\]

\[
v_j : velocity of affect value's variation for j-th basis
\]

\[
b_i : radius of emotional boundary for i-th emotion
\]
If the current emotion \(e\) generated by (1) is out of the target emotion’s boundary \(b_i\), we use the original emotion vector \(e\) to generate facial expressions. However, if the current emotion is within the boundary \(b_i\), we add random variation to each affect value. The degree of variation depends on the characteristics of the affect space basis and the type of emotion. The degree of variation is directly proportional to radius of emotional boundary and velocity of affect values variation, which represents the characteristics of the affect space basis. We thus generate affect values slightly different from the real target position values. These results in dynamic expressions which follow directly from the random-varied emotion since the transition matrix \(T_f\) transfers all the points in affect space to expression space using (2). Here, we used \(e\) instead of \(e_i\), so that we have different facial expressions at different time even though the robot has the same emotional states. We also have dynamic facial expression even though the robot emotional states stay on one target position. Therefore, the robot is less boring and more lifelike.

The range of variation can be critical. If it is too wide, the original emotional state will be scattered, and the facial expression will be awkward. If it is too narrow, dynamic expressions are reduced. Therefore, we picked a range of variation empirically. We also adjusted the degree of variation according to the characteristics of each basis using \(v_i\).

3. Experimental Results

We made a robot simulator \(FRESi\) (Facial Robot Expression Simulator) using Macromedia Flash 8.0. \(FRESi\) has 13 DOFs: 4DOFs in eyebrows, 4 DOFs in eyelids, 5 DOFs in mouth.

As a result of the linear affect-expression space model[8], \(FRESi\) has a 4-dimensional affect space, so we added random variation to four bases. Fig. 2 (a) shows the change of each basis value under random variations and Fig. 2 (b) is original values for sadness. Fig. 1 shows the change of facial expression corresponding to Fig. 2 (a). The facial expression image sequence does not quite illustrate the effectiveness of our proposed model. However, a video of the facial expression changes can be found at the following URL: http://cheonji.kaist.ac.kr/avi/FRESi.avi.

Fig. 1. Facial expression variation for sadness.

**Fig. 2.** Affect value with variation and without variation for sadness on \(FRESi\).

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### References


