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Feeling Communication Feasibility Using Facial Expression Analysis/Synthesis Based on Individual Model

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Inadequate recognition of feelings due to differences in age or culture often interferes with mutual understanding. In this paper, a "feeling" communication system which enables users to convey feelings more accurately by modeling individual differences of facial expression as "Individual Models" is proposed. Through the use of "Individual Models", this communication system extracts and transmits the meaning of a user's facial expression to other users. A suitable facial expression (one that conveys the user's true meaning) is then synthesized and presented on an individual basis to other users, thus helping user's to bridge cultural barriers.

1. Introduction

It is said that Japanese people are poor at expressing their feelings, especially in international communications comprehensible to other nationalities. Therefore, when the people from other countries try to understand a Japanese person's feelings from their facial expressions, inadequate recognition of feelings often interferes with mutual understanding during international communication. As a possible partial solution, more precise facial image transmission utilizing high-speed networks and high-resolution displays coupled with high-performance microprocessors is now available. In addition, analysis/synthesis image coding which extracts facial features from facial expression and transmits them at very low bit rates has been investigated [1)~6)]. However, because these methods do not consider the differences between individual facial expressions, they are not very practical.

In our research, we have developed a system which enables the cultivation of mutual understanding by the combination of a video communication system and our "feeling" communication system. The feeling communication system we propose makes it possible to convey more accurately feelings by the execution of the following processes:

Prior to communication session,

(1) to extract general expression patterns of facial muscle motion,

(2) to construct an analytical individual model, which takes advantages of the differences between general and individual expression patterns,

(3) to establish general expression deformation rules of all expressions so that people can understand each other.

(4) to construct a synthetic individual model, which takes advantages of the differences between general and individual expression deformation rules,

During a communication session,

(1) to generalize an expression pattern using the analytical individual model,

(2) to extract actual feelings using pattern matching,

(3) to personalize general expression deformation rules using the synthetic individual model and

(4) expression synthesis which enables one to convey one's accurate feelings to facilitate communication with another person using computer graphics (CG).

We feel that this feeling communication system will be very useful for communications between people who do not know each other but need to understand each other well.

2. Feelings, Facial Expressions and Individual Models

In general, there are three ways mainly that people express their feelings, facial expressions, gestures[7)] and languages. However, facial expression is more direct and effecient than the others, therefore we selected facial expression as the best way to convey a person's feelings.

In our system, six feelings including happiness, anger, sadness, surprise, fear and disgust,

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and a measure of the degree to which these feelings are expressed are considered. In addition, we defined a general expression which is expressed by most people, and an individual expression which is expressed by a specific person. We regarded the relations between feelings, general expressions and individual expressions as mapping as shown in **Fig. 1**. Arbitrary general expression E_{gen} to one feeling can be obtained by mapping g, an arbitrary individual expression $E_{indiv,analy}$ (*analy* means analysis side) and an arbitrary expression for one person $E_{indiv,synth}$ (*synth* means synthesis side) to one general expression obtained by mapping h_{analy} and mapping h_{synth}, respectively as expressed in Eqs. (1), (2) and (3).

$$g(F) = E_{gen} \quad (1)$$
$$h_{analy}(E_{gen}) = E_{indiv,analy} \quad (2)$$
$$h_{synth}(E_{gen}) = E_{indiv,synth} \quad (3)$$

We defined an analytical individual model which can express the differences between a general person and an individual in their expressions. The analytical individual model is applied for the mapping h_{analy}^{-1} which converts an individual expression to a general expression. We also defined a synthetic individual model which can express the differences between a general person and an individual in their expressions for the extracted feeling from the analysis side. A synthetic individual model is applied for the mapping h_{synth} which converts a general expression to an individual expression.

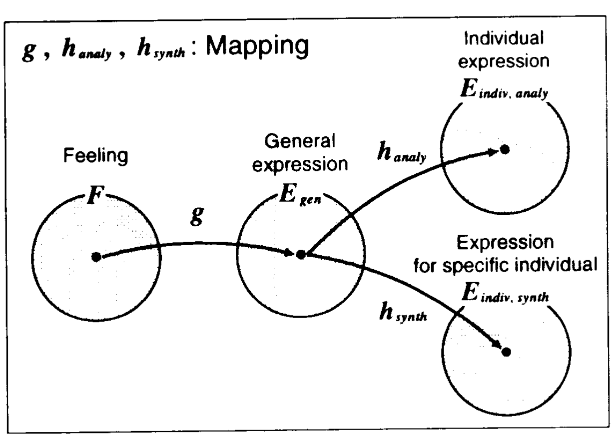


Fig. 1 Relations between feelings and facial expressions.

3. Feeling Communication using Individual Models

Figure 2 shows an example of "feeling" communication using an individual model. It is assumed that user A who is reserved in her expression is communicating with user B who absorbs more strongly expressed feeling (in this case, we will label this a "moderate" expression).

(1) Although now user A's actual feeling is "Very Happy", her expression looks as if her feeling were a "Little Happy". This facial image ("Little Happy" expression) can be captured by a video camera.

(2) Her "Little Happy" expression is generalized using user A's analytical individual model. Eventually, user A's actual feeling ("Very Happy") is determined. Then, the information of the feeling is transmitted to user B on the synthesis side.

(3) User A's actual feeling ("Very Happy") is converted to a general expression corresponding to it and personalized. Finally, an equivalent expression through which user B can understand user A's actual feeling (a little exaggerated in comparison to the original expression) is synthesized.

(4) Thus, user B can understand user A's actual feeling ("Very Happy") by seeing the displayed facial image.

It is desired that not only human facial ex-

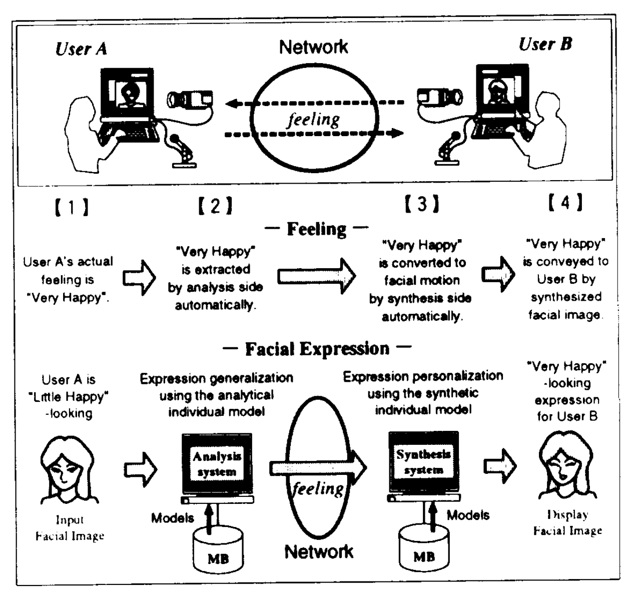


Fig. 2 Feeling communication using individual models.

pression but also facial animation, voice and text etc., can be used as the ways to convey personal feelings.

4. Models for Facial Expression Analysis

In order to execute facial expression analysis and accurate feeling extraction on the analysis side, the following models are used.

- 3-dimensional wire frame model (3-D WFM) which shows facial shape shown in **Fig. 3**.
- Relationship between feelings and general expressions
- General expression patterns
- Analytical individual model

There is a general expression pattern corresponding to each feeling. On the analysis side, facial expressions are processed as 2-D data because it is easier to extract the features from 2-D data than 3-D data.

4.1 Modeling of Facial Expression on Analysis Side

A facial expression model is obtained in the form of a 2-D matrix as expression patterns which characterize the motions at the feature points on the face. Twenty six points on the face as feature points which are regarded as features of expressions made by the human face are defined as shown in **Fig. 4** a)[1]. The motions at the feature points are obtained in the form of 2-D motion vector, $\alpha_i e^{j\theta_i}$, where α_i is the motion distance and θ_i is the motion direction (shown in Fig. 4 b)).

An individual expression pattern E_{indiv} is expressed by the 26 motion vectors at the feature points.

$$E_{indiv} = \left[\alpha_1^{j\theta_1}\ \alpha_2^{j\theta_2} \cdots \alpha_{26}^{j\theta_{26}}\right]^T = [a_1 + jb_1 \cdots a_{26} + jb_{26}]^T \quad (4)$$

A general expression pattern E_{gen}^f ($1 \le f \le 7$ is an index of single feeling) is expressed by the motion vectors obtained by averaging the real part and the imaginary part of a number of individual expression patterns.

$$E_{gen}^f = \left[\overline{a_{f,1}} + j\overline{b_{f,1}} \cdots \overline{a_{f,26}} + j\overline{b_{f,26}}\right]^T \quad (5)$$

The general expression pattern corresponding to non-expression is expressed by 26 zero vectors. We defined the norm of facial expression as a coefficient which is expressed by the total value of the motion distance between the expression and the non-expression, and is calculated using the following equations (Eq. (6) for the norm of the individual expression and Eq. (7) for the norm of the general expression):

$$D_{indiv} = \sum_{i=1}^{26} \sqrt{a_i^2 + b_i^2} \quad (6)$$

$$D_{gen} = \sum_{i=1}^{26} \sqrt{\overline{a_i}^2 + \overline{b_i}^2} \quad (7)$$

4.2 Analytical Individual Model on Analysis Side

The analytical individual model is defined as a 2-D matrix which shows the differences between a generic person's motion vector and an individual motion vector of the feature points corresponding to one feeling. The relation between a general expression pattern E_{gen} and an individual expression pattern E_{indiv} is defined using the analytical individual model M_{analy} as in the following equation:

$$E_{gen} = M_{analy} E_{indiv} \quad (8)$$

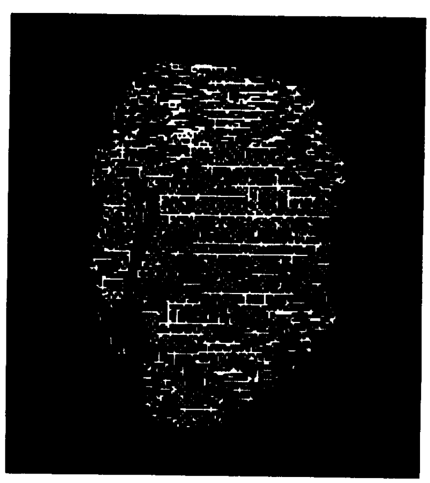


Fig. 3 3-Dimensional Wire Frame Model (3-D WFM).

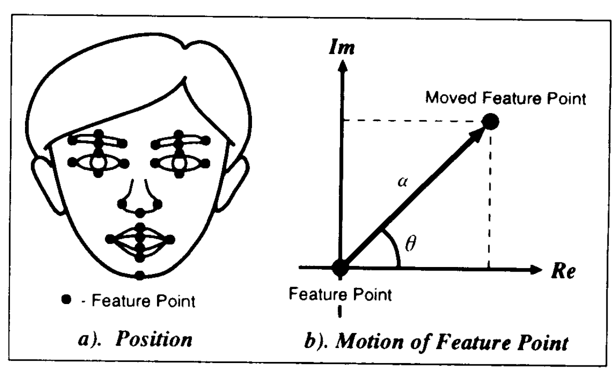


Fig. 4 Feature points.

where

$$M_{analy} = \begin{bmatrix} m_{1,1} & \cdots & m_{1,26} \\ \vdots & \ddots & \vdots \\ m_{26,1} & \cdots & m_{26,26} \end{bmatrix} \quad (9)$$

Then, the elements of the analytical individual model; $m_{i,i}$ are calculated using the following equation through Eqs. (4), (5), (8) and (9).

$$m_{i,i} = \lambda_{i,i} e^{j\omega_{i,i}} \quad (10)$$

$$\lambda_{i,i} = \frac{\sqrt{\overline{a_i}^2 + \overline{b_i}^2}}{\sqrt{a_i^2 + b_i^2}}$$

$$\omega_{i,i} = \tan^{-1}\left(\frac{\overline{b_i}}{\overline{a_i}}\right) - \tan^{-1}\left(\frac{b_i}{a_i}\right)$$

Similar to the general expression patterns, there is an analytical individual model corresponding to each feeling. In the case of non-expression, the analytical individual model M_{analy} becomes a unit matrix.

5. Models for Facial Expression Synthesis

In order to synthesize facial expression that can convey a person's feelings in the synthesis side, the following models are used.

- 3-D WFM
- Relationship between feelings and general expressions
- The general expression deformation rules (general model)
- Synthetic individual model

There is a general model corresponding to each feeling, similar to the analysis side as will be described in the following section.

5.1 Modeling of Facial Expression on the Synthesis Side

The facial expression model processed on the synthesis side is a combination of the Action Unit (AU) described in the facial action coding system (FACS)[8]. The AUs are a set of minimal basic actions. All facial expressions can be expressed by AU combinations. In addition, keynodes are defined as nodes which are the central points of the motions of the AU. There are 55 points in our research as shown in **Fig. 5** c). Each AU's expression deformation rule is defined as a motion matrix which is a set of the 3-D motion vectors of the keynodes. Figure 5 b) shows an example as model of an expression. Within a region of a AU, the nodes of the movement in the WFM follow the motion vectors of keynodes.

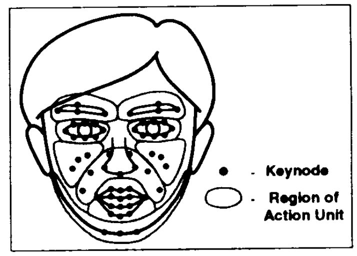
An individual motion matrix V^i_{indiv} with the

AU No.	AU Name	AU No.	AU Name
1	Inner brow raise	10	Upper lip raise
2	Outer brow raise	12	Lip corner pull
4	Brow lower	15	Lip corner depression
5	Upper eyelid raise	17	Jaw lower
6	Cheek raise	20	Lip stretch
7	Eyelid stretch	25	Lower lip lower
9	Nasal furrow	26	Lower lip lower followed jaw lower

a). Examples of AU

Expression	AU No.(example)
Happy	6+12+26
anger	4+5+7+10+26
sadness	1+4+15
surprise	1+2+5+26
fear	1+2+4+5+7+20+26
disgust	4+9+17

b). Modeling of Expression using AU



c). Keynode and Regions of AU

Fig. 5 AU, expression and keynodes.

AU_i which is AU with the number i is expressed by the 3-D motion vector of the keynodes within the region of AU_i, and is defined as in the following equations:

$$V^i_{indiv} = [v_{i,1} \cdots v_{i,n_i}]^T \quad (11)$$

and

$$v_{i,k} = \{x_{i,k}, y_{i,k}, z_{i,k}\}^T \quad (12)$$

where n_i is the number of keynodes within the region of the AU_i and k $(1 \leq k \leq n_i)$ is the arbitrary number of n_i. A general motion matrix V^i_{gen} is defined as in the following equations:

$$V^i_{gen} = [\overline{v_{i,1}} \cdots \overline{v_{i,n_i}}]^T \quad (13)$$

and

$$v_{i,k} = \{\overline{x_{i,k}}, \overline{y_{i,k}}, \overline{z_{i,k}}\}^T \quad (14)$$

5.2 Synthetic Individual Model on the Synthesis Side

The synthetic individual model is defined as a model which is expressed by a coefficient matrix which reflects the differences between the motion of expression by which most people can correctly understand a person's feeling and the motion of expression by which one individual can also correctly understand the same person's feeling.

The relation between a general motion matrix V^i_{gen} of AU_i (where number of keynodes within the region of AU_i is n_i) and an individual motion matrix V^i_{indiv} of AU_i is defined using the synthetic individual model M^i_{synth} corresponding to AU_i as in the following equation:

$$V^i_{indiv} = M^i_{synth} V^i_{gen} \quad (15)$$

Then, the synthetic individual model M^i_{synth} is calculated using the following two equations (16) and (17):

$$M^i_{synth} = \begin{bmatrix} M'_{i,1} & & 0 \\ & \ddots & \\ 0 & & M'_{i,n_i} \end{bmatrix} \quad (16)$$

where

$$M'_{i,k} = \begin{bmatrix} x_{i,k}/\overline{x_{i,k}} & 0 & 0 \\ 0 & y_{i,k}/\overline{y_{i,k}} & 0 \\ 0 & 0 & z_{i,k}/\overline{z_{i,k}} \end{bmatrix} \quad (17)$$

6. Feeling Communication System

In this section, we describe a processing flow in our "feeling" communication system. **Figure 6** shows the system architecture of the feeling communication system. Both the analytical and synthetic individual models described in Section 4, 5 are stored in a model-base in advance.

(1) Video camera gets a facial image.

(2) **WFM Ajustment:** WFM is adjusted to the actual facial image, and the individual motions of the feature points are detected.

(3) **Expression Pattern Extraction:** An individual expression pattern E_{indiv} is generated using the individual motion of the feature points.

(4) **Expression Generalization:** An individual expression pattern E_{indiv} is converted to a generalized expression pattern E'_{gen} by the following two equations using the analytical individual model, and the norm of the generalized expression D'_{gen} is calculated:

$$E'_{gen} = M_{analy} E_{indiv} = [p_1 + jq_1 \cdots p_{26} + jq_{26}]^T \quad (18)$$

$$D'_{gen} = \frac{1}{26} \sum_{i=1}^{26} \sqrt{p_i^2 + q_i^2} \quad (19)$$

(5) **Feeling Decision:** A feeling is determined by comparing the error Err_f (where $1 \leq f \leq 7$ is an index of single feeling) of the generalized expression pattern E'_{gen} (Eq. (18)) and each general expression pattern E^f_{gen} (Eq. (5)), which is stored in the model-base, using the following equation.

$$Err_f = \sum_{i=1}^{26} (Err_{move} \times w_{f,i}) \quad (20)$$

$$Err_{move} = Err^2_{real} + Err^2_{imag}$$

$$Err_{real} = \overline{a_{f,i}} - K_f p_i$$

$$Err_{imag} = \overline{b_{f,i}} - K_f q_i$$

where K_f is a coefficient which shows the degree of the feeling calculated using the norm of the generalized expression D'_{gen} (Eq. (19)) and the norm of each general expression D^f_{gen} (Eq. (7)).

$$K_f = \begin{cases} D^f_{gen} \;/\; D'_{gen} \\ 1 \; (non-expression) \end{cases} \quad (21)$$

Since the degree of feeling for non-expression does not exist, $K_f = 1$. $w_{f,i}$, a weighting value to emphasize individual features is calculated using the following equation:

$$w_{f,i} = 26 \times \frac{|\alpha_{f,i} - \overline{\alpha_{f,i}}|}{\sum_{j=0}^{26} |\alpha_{f,j} - \overline{\alpha_{f,j}}|} \quad (22)$$

When the motion of the feature points characterizes the specific user's feeling, the weighting value $w_{f,i}$ of the feature points must be larger than other points. Therefore, by calculating the $w_{f,i}$ more suitable "feeling" can be determined.

(6) A feeling information consisting of a pair of the word which shows the feeling (e.g. happiness, surprise) and the coefficient which shows the degree of the feeling (K_f) are transmitted from the analysis

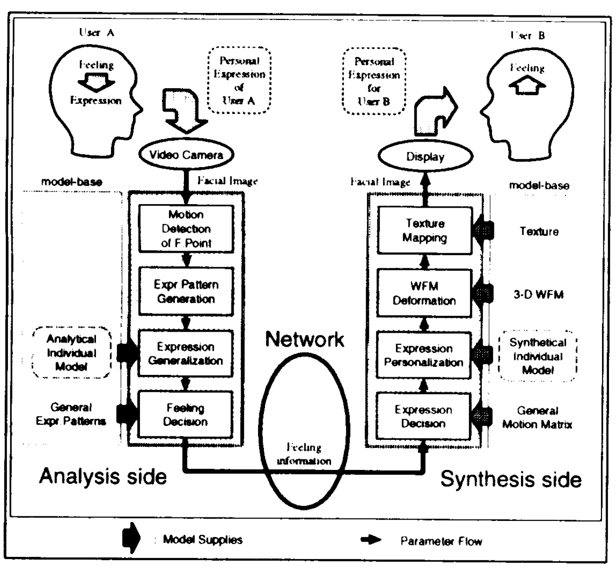


Fig. 6 System architecture.

side to the synthesis side.

(7) **Expression Decision:** A combination of the AU numbers corresponding to the feeling information received from the analysis side is obtained and all of the general motion matrices corresponding to each AU number are obtained from the model-base.

(8) **Expression Personalization:** An individual motion matrix V^i_{indiv} of AU_i (where i is an AU number) is calculated using a general motion matrix V^i_{gen} of the AU_i and the synthetic individual model M^i_{synth} corresponding to AU_i by the following equation:

$$V^i_{indiv} = \frac{1}{K_f} M^i_{synth} V^i_{gen} \quad (23)$$

(9) **WFM Deformation:** The nodes of WFM within the region of the AUs are moved based on each individual motion matrix M^i_{synth} corresponding to these AU_i.

(10) **Texture Mapping:** Texture mapping is executed to display a more realistic human face.

(11) Finally, a synthetic facial image is displayed on the monitor.

7. Evaluations of Analytical Individual Model

In order to verify our facial communication and the individual model, we evaluated the analytical individual model on the analysis side on 14 university students using the following processes:

(1) We made all students make "happiness" expressions with 3 different levels of degree including "little", "normal" and "very", measured the movement of these expressions using the measurement equipment which enables the measurement of the 3-dimensional shape of the curved surface. In all, 9 expressions for each person and 42 expressions in total were measured.

(2) Similarly, we measured the movement of the "anger", "sadness" and "surprise" expressions. However, we measured expressions about "anger" and "sadness" with 2 levels of degree including "normal" and "very" because the expressions representing "little" anger and sadness feelings were difficult to make intentionally. Furthermore, since "fear" and "disgust" expressions were also difficult to make intentionally, we could not evaluate these expressions.

(3) The motion distance and motion direction were calculated from the coordinates of the feature points by a non-expression and the expressions with feelings. Then the individual expression patterns for all the numbers were generated using Eq. (4).

(4) For each feeling (e.g., little-happiness, very-surprised), the individual expression patterns of all the members were averaged and general expression patterns were generated using Eq. (5).

(5) For each person, the analytical individual model about "normal" feelings was calculated using Eqs. (8), (9) and (10) from the individual expression pattern E_{indiv} obtained using Eq. (4), which expresses "normal" feeling and a general expression pattern E_{gen} using Eq. (5) about each "normal" feeling. Similarly, the analytical individual models about "little" and "very" feeling were calculated.

(6) We analyzed all of the measured expressions through the facial communication system on the analysis side and calculated the feeling recognition ratio (FRR) which shows how our individual model correctly adjust to differences of individual expression using Eq. (24).

$$FRR = \frac{N_{success}}{N_{analysis}} \times 100\ [\%] \quad (24)$$

$N_{success}$: The number of the expressions analyzed correctly.

$N_{analysis}$: The total number of the analysis for each feeling.

About the following two items including (1), (2), we calculated FRRs.

(1) The FRRs for each feeling.

(2) The FRRs for each level of degree of feeling.

(7) We compared FRRs in the following cases to evaluate efficiency of the analytical individual model.

case 1: Not using the analytical individual model.

case 2: Using the analytical individual model about "normal" feeling.

case 3: Using the analytical individual model about "normal" feeling and weighting value calculated using Eq. (22).

case 4: Using three analytical individual models about "little", "normal" and "very" feeling.

case 5: Reduction of the number of feature points and using three analytical individual models.

Where in case 1 and case 2, all of the weighting value of feature points $w_{f,i}$ were equal to 1.

Table 1 shows the total number of measured and analyzed expressions.

7.1 Efficiency of the Analytical Individual Model

We compared FRR in following cases to evaluate efficiency of the analytical individual model.

case 1: Not using the analytical individual model.

case 2: Using the analytical individual model about "normal" feeling.

Table 2 shows the FRRs to each feeling and **Table 3** shows the FRRs to each degree of the feeling.

From Table 2, it is clear that analysis in the case of using the analytical individual model is more accurate than that of not using the analytical individual model. This means using the analytical individual model is effective to identify feelings accurately. From Table 3, the use of the analytical individual model can also provide more correct decision of feeling for normal expressions, though feeling recognitions for the degrees of "little" and "very" are not very accurate. The reasons for these low accuracies are;

- The analytical individual model constructed using only the expressions of "normal" feeling was insufficient because the degree of expression was not a linear scale of the motions for the expressions.
- When the degree of the feeling is small, accurate depiction of feeling can not be identified because of the measurement error for the facial motions.

Table 1 Number of expressions.

	little	normal	very	total
happiness	42	42	42	126
anger	0	42	42	84
sadness	0	42	42	84
surprise	42	42	42	126
total	84	168	168	420

Table 2 FRRs to four feelings (1) [%].

	case 1	case 2
Happiness	10.3	69.0
Anger	82.1	82.1
Sadness	17.9	82.1
Surprise	71.4	61.1

Table 3 FRRs to three degrees of the feeling (1) [%].

	case 1	case 2
Little	35.7	32.1
Normal	39.9	98.2
Very	53.6	65.5

7.2 Consideration to the Scale of the Degree of the Feeling

In previous paragraph, we found that the expression analysis which used the analytical individual model about "normal" feeling only was not consider the scale of the degree of the feeling. To resolve this problem, we analyzed using not only the analytical individual model about "normal" feeling but also the analytical individual models about "little" and "very" feelings.

In case of using the three analytical individual models about "little", "normal" and "very" feelings, one analytical individual model about one degree of the feeling must be selected from three models. Then, in case of using one analytical individual model about "normal" feeling only, the degree of the feeling is determined after the expression generalization process, but in this case, the degree of the feeling is determined in this process before the expression generalization process. The analytical individual model used in the expression analysis selects by the following process.

(1) The norms of individual expressions about each feeling (e.g. little-happiness, very-surprise) were calculated using Eq. (6) from individual expression patterns calculated from measured data and stored as a reference table as shown in **Fig. 7** into model-base in advance.

(2) The norm of expression was divided into three levels corresponding to the three degrees of the feeling, including "little", "normal" and "very" by determination of high, low and bottom threshold using the norms of individual expressions about each feeling from the refference table (see Fig. 7). Now, a high threshold is an average of the norms of the individual expression which expresses "very" feeling and the individual expression which expresses "normal" feeling, a low threshold is an average of the norms of the indi-

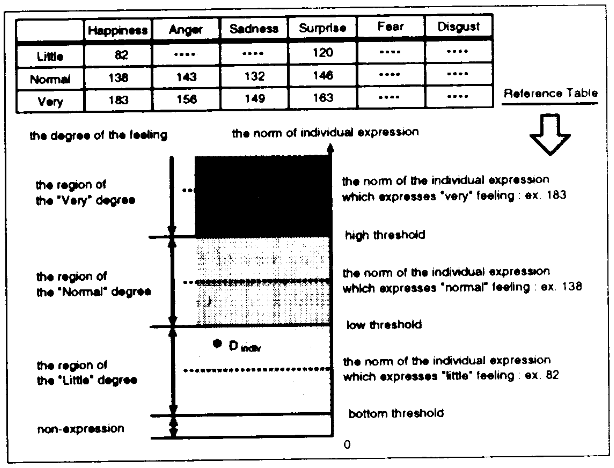


Fig. 7 Determination of the degree of the feeling.

vidual expression which expresses "normal" feeling and the individual expression which expresses "little" feeling, and the bottom threshold is equal to zero.

(3) The norm of individual expression captured by a video camera D_{indiv} was calculated using Eq. (6). If D_{indiv} is more than a high threshold, the word which shows the degree of the feeling is "very". If D_{indiv} is more than a low threshold and less than a high threshold, it is "normal". If D_{indiv} is more than a bottom threshold and less than a low threshold, it is "little". If D_{indiv} is otherwise, the analyzed expression is the non-expression. In figure, the word which shows the degree of the feeling is "little".

We compared FRRs in following cases to evaluate this analysis method using the analytical individual model about "little", "normal" and "very" feelings.

case 2: Using the analytical individual model about "normal" feeling.

case 4: Using three analytical individual models.

Table 4 shows the FRRs to each feeling and **Table 5** shows the FRRs to each degree of the feeling.

As shown in Table 4, in case 4, enough FRRs were obtained about all feelings because high FRRs were obtained about not only "normal" feeling but also "little" and "very" feelings as shown in Table 5. Namely, This shows that the scale of the degree of the feeling can be considered by use of three analytical individual models about three degrees of the feeling.

Table 4 FRRs to four feelings (2) [%].

	case 2	case 4
Happiness	69.0	98.4
Anger	82.1	100.0
Sadness	82.1	98.8
Surprise	61.1	96.8

Table 5 FRRs to three degrees of the feeling (2) [%].

	case 2	case 4
Little	32.1	95.2
Normal	98.2	98.8
Very	65.5	99.4

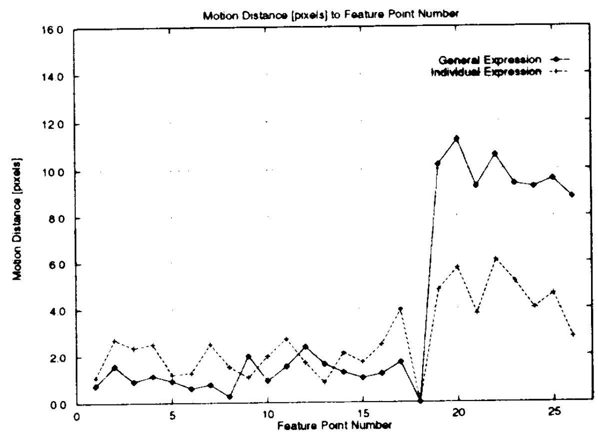


Fig. 8 Differences of motion and distance of feature points between general expression and individual expression.

7.3 Consideration of Characteristics of Individual Expression

Until now, We used 26 feature points shown in Fig. 4 in facial expression analysis. But if features of individual expression are considered, it is considered that accurate analysis is possible by use of a small number of feature points. Then we reduced the number of feature point, analyzed and considered about this problem through results of analysis.

7.3.1 Introduction of Weighting Value

The number of feature point is reduced by consideration of weighting value. Weighting value is calculated using Eq. (22) described in Section 6.

Figure 8 shows the differences of the motion distance of feature points between general expression and individual expression of one person. Because it is considered that differences between general expression and individual expression show features of individual expression, if the difference of one feature point is larger, that the feature point shows more an important feature of individual expression and weighting

Table 6 FRRs to four feelings (3) [%].

	case 2	case 3
Happiness	69.0	66.7
Anger	82.1	82.1
Sadness	82.1	85.7
Surprise	61.1	73.0

Table 7 FRRs to three degrees of the feeling (3) [%].

	case 2	case 3
Little	32.1	35.7
Normal	98.2	98.2
Very	57.7	72.6

Table 8 FRRs to four feelings (4) [%].

	case 4	case 5
Happiness	98.4	97.6
Anger	100.0	98.8
Sadness	98.8	95.2
Surprise	96.8	100.0

Table 9 FRRs to three degrees of the feeling (4) [%].

	case 4	case 5
Little	95.2	100.0
Normal	98.8	98.2
Very	99.4	97.0

value is larger by Eq. (22).

We compared FRRs in following cases to evaluated efficiency of weighting.

case 2: Using the analytical individual model about "normal" feeling.

case 3: Using the analytical individual model about "normal" feeling and wèighting value calculated using Eq. (22).

Table 6 shows the FRRs to each feeling and **Table 7** shows the FRRs to each degree of the feeling.

As shown in Table 6, especially, FRR to "surprise" improved. And as shown in Table 7, FRR to "very" improved. It is considered that features of individual expression are more clearly expressed because the motion of feature points of expression expressed "very" feeling is large, and accuracy of analysis side was improved by consideration of the features of individual expression using a weighting value. Then we found that use of a weighting value is effective.

7.3.2 Reduction of the Number of Feature Point

Because feature points that have a weighting value are larger expresses features of individual expression, we selected 10 feature points in which a weighting value is larger, recognized feelings by analysis of the motion of these feature points. Beside, in this case, one person's selected feature points do not correspond with another person's selected feature points because these feature points are points which consider features of individual expression.

We compared FRRs in the following cases to examine the effect to accuracy of analysis by reduction of the number of feature points.

case 4: Using all the analytical individual models about "little", "normal" and "very" feelings.

case 5: Reduction of the number of feature points and using all the analytical individual models.

Table 8 shows the FRRs to each feeling and **Table 9** shows the FRRs to each degree of the feeling.

As shown in Table 8 and Table 9, enough FRRs were obtained. Then we found that accurate analysis was possible by use of feature points considered features of individual expression even if the number of feature points was reduced.

8. Synthetic Individual Model

The synthetic individual model on the synthesis side is the one which transfers the general facial expression to the specific facial expression which could be understood by the user on the receiving side. The accuracy of the individual model depends on the results of the actual user's evaluation for the synthesized expression whether the accurate feeling of the partner on the receiving side can be understood or not. Therefore, the individual model can be developed by repeating the following process until the user can be satisfied with the synthesized expression model to understand the real feelings of his partner.

(1) Initialize the matrix of the individual model, $M_{synth}(i)$, $i = 0$ to unit matrix.

(2) Synthesize the general facial expression, V_{gen} for the known feeling, say "happiness".

(3) Transfer the general facial expression, V_{gen} to the individual facial expression, $V_{indiv}(i)$ in the following equation:

$$V_{indiv}(i) = M_{synth}(i)\, V_{gen} \quad (25)$$

(4) Evaluate and correct the individual facial expression by changing the movements of the major parts on the face to feel satisfaction.

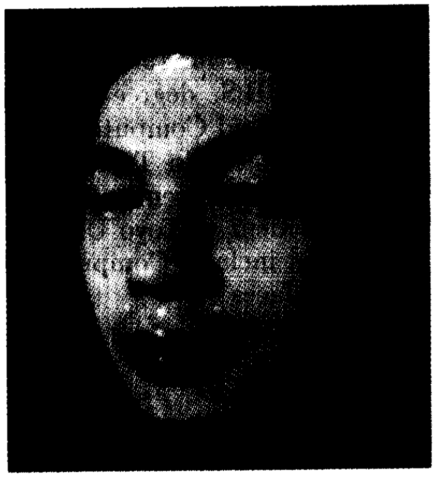


Fig. 9 Facial image of non-expression.

Fig. 10 Facial image expressing "happiness".

$$V_{indiv}(i) \rightarrow V_{indiv}(i+1)$$

(5) Update the matrix $M_{synth}(i+1)$ by using the following equation:

$$V_{indiv}(i+1) = M_{synth}(i+1)\,V_{gen} \qquad (26)$$

Steps 3 through 5 are repeated for the other different feelings.

Thus, the individual model will learn the feeling of the user. We implemented the synthesis expression system based on the CG system. **Figure 9** shows the facial expression image of the person on the analytical side without any feeling expression. **Figure 10** indicates a general facial expression image for "happy" feeling. The user evaluates and corrects this facial expression image by changing the movements of the major parts on the face to feel satisfaction so as to develop his individual model M_{synth}. However, we are now developing a tool to interactively correct the facial expression and update matrix value of the individual model.

9. Conclusion

In this paper, we proposed a "feeling" communication system and introduced individual models and modeling of facial expressions. This system can not only convey an actual person's feelings, but also supports accurate mutual understanding in communications by showing the relationship between actual expression and actual feeling.

We feel our "feeling" communication system is able to execute accurate feeling recognition from real facial images on the analysis side and virtual images using CG and expression deformation based on the motion matrix as shown in Section 8. Further studies are required to solve various problems so as to raise the accuracy of feeling recognition as well as provide more accurate synthetic facial images.

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