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The Open Automation and Control Systems Journal, 2014, *6*, 1205-1211 1205

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Research on Facial Expression Recognition based on Motion Unit Combination Feature Matrix and Supporting Vector Machine

Shi Shui-e[1,*] and Guo Rong-yan[2]

[1]*College of Physics and Electronic Engineering, Henan Normal University, Xinxiang 453007, China*

[2]*School of Physics and Mechanical & Electrical Engineering, Zhoukou Normal University, Zhoukou, Henan, 466001, China*

Abstract: Based on Haar and Adaboost methods, this paper uses genetic algorithm and cloud computing, collaborative simulation to improve facial expression recognition algorithm. It uses genetic algorithm to encode the movement element local feature combination, which improves marked effect of facial organslocal feature region. It uses cloud computing collaborative simulation topology to establish facial local feature generalized matrix, which enhanced the calculation speed of the support vector machine expression classifier. In order to verify the efficiency and accuracy of the algorithm, this paper tests the facial expressions of the same individuals and different individuals using expression library. Throguh testing it is found that the improved method has higher facial expression recognition rate, faster computing speed and better performance. Throguh the analysis of results, the improved algorithm has higher facial expression recognition rate and it is higher in the same individual and different individuals, and the recognition rate of different individuals is the same as the average recognition rate, which verifies the reliability of the algorithm and provides a new method for the design of facial expression recognition algorithm.

Keywords: Haar, Adaboost, Motion unit, Characteristic matrix, Cloud computing, Supporting vector machine.

1. INTRODUCTION

Computer is difficult to recognize people compared to human self, the main reasons is that in a recognition process, the computer needs to establish characteristics expression and emotion classification of human facial expression model at the same time, but also they need be connected [1, 2]. The face is a flexible body, and it is very difficult to associate facial movement with facial expression using a fixed pattern, in addition, the facial expression is diversity. Facial expressions produce subtle changes due to inner emotional, so it is the difficulty of facial expression recognition.

Facial expression recognition algorithm has gone through three stages [3]: the first stage is the face recognition or texture recognition is applied to facial expression recognition, the most commonly used features are Haar feature, LBP feature and Gabor feature, and the most commonly used classifiers are mainly SVM, Adaboost and neural network [4]. For example, Kobayashi used the neural network method for facial expression recognition; Yin Xingyun *et al.* use the hidden Markov model for facial expression recognition, and good results have been obtained; In the second stage, most of the work is around the unique characteristics of facial expression, such as Donate and Tian proposed motion unit recognition. Combined context information of facial features in the template matching Ding achieves a precise positioning of facial motion unit. The third stage is from two aspects, including information collection and classification [5, 6]. By simulating the macaque from retina to visual neurons, Gu put forward the local feature extracting based on jurisdiction coding. Through the simulation of biological visual response mechanism, Wright proposed a classification method based on sparse coding, and proved that SRC can solve the occlusion and noise problem in the face recognition.

There are two prominent problems in the system design process of facial expression recognition: one of them is the recognition rate, the other is the calculation speed [7]. Based on this, this paper designs the overall framework of the facial expression recognition, as shown in Fig. (**1**).

Fig. (**1**) shows the basic framework of facial expression recognition system designed in this paper. The cloud collaborative computing algorithm is based on multi-core and parallel computing, and it can effectively improve the computational efficiency of the classifier. The genetic algorithm coding can mark on facial motion unit feature, which improves the samples training speed, lowers the accuracy of recognition and reduces error rate [8]. So, genetic algorithm and cloud collaborative computing are the main technologies of system optimization.

2. FEATURE EXTRACTION METHOD BASED ON FACIAL MOTION UNIT

Whitehill uses many advanced algorithms in the smile recognition method and different algorithms are compared,

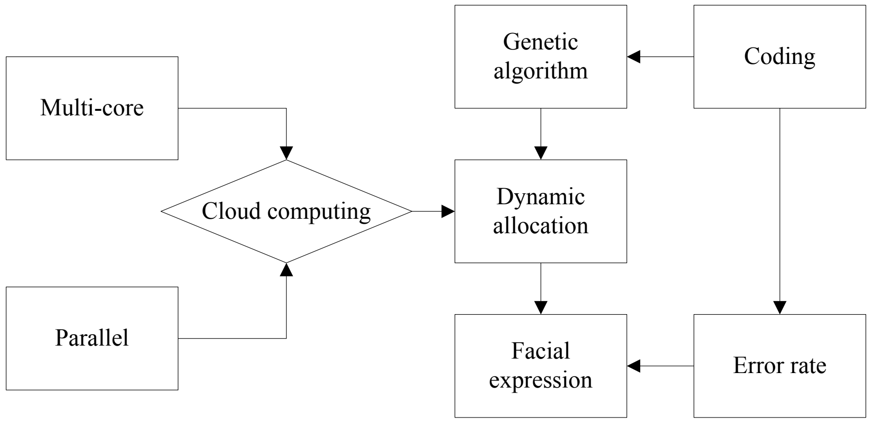

Fig. (1). The basic framework of facial expression recognition system.

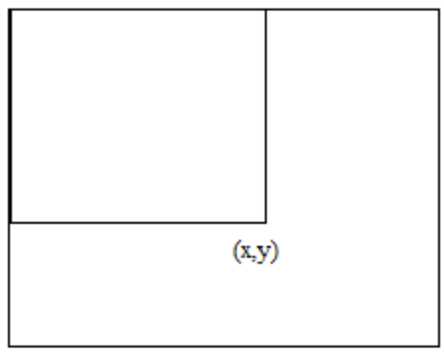

Fig. (2). Schematic diagram of integral image.

finally it is indicated that the best expression recognition effect is Gabor+SVM and Haar+Adaboost [9]. Therefore, a facial expression recognition method based on the framework of Haar+Adabosst face recognition has very strong practicability. In 2010 Liu Qingshan *et al.* proposed a facial expression recognition method based on component characteristics of facial motion unit. Through the verification of expression database, this algorithm has more advantages than the general Haar+Adaboos method [10]. But there are some defects on selecting component characteristics of facial motion unit, so facial motion unit combination characteristics are proposed instead of component characteristics.

2.1. The Extracting Method of Facial Motion Unit Combination Characteristics

In the classic face recognition, Viola uses three types fo Haar features, also known as rectangle feature. The number of rectangle features is very large, if computing directly it will expend very large computational resources, therefore it needs to introduce the concept of integral graph, as shown in Fig. (**2**).

As shown in Fig. (**2**), it uses pixels point of the left rectangle of and *(x, y)* to define integral image,

$$tt(x,y)=\sum_{x'<z,y'<y} t(x',y') \tag{1}$$

$$s(x,y)=s(x,y-1)+t(x,y) \tag{2}$$

Where $s(x,y)$ is the rows accumulating of pixels. For the convenience of calculation, it can initialize iteration, $s(x,-1)=0$ and $tt(-1,y)=0$. The method can be used to quickly compute the integral image, which can extract the facial unit fast. Based on the facial motion unit composition characteristics expression recognition method, it improves classical Haar+Adaboost algorithm, and it is realized through two parts, the first part is the main character integration, each integration characteristic is relative to a set of facial motion unit. The main steps of the algorithm are as follows [11]:

(1) Collecting the sample image and extract local Haar feature. p isl e local area number, $p=1,2,\cdots,49$;

(2) using the expression classifier supporting vector machine, so error rate of each local feature is c;

(3) Selecting the n features with minimum error rate to compose new combination feature Z;

(4) The rest of local features uses face classifier of supporting vector machines, if the error rate is reduced, then continue to join the combination characteristic Z;

(5) Repeat the step(4), when the error rate is the lowest, record the combination characteristic Z.

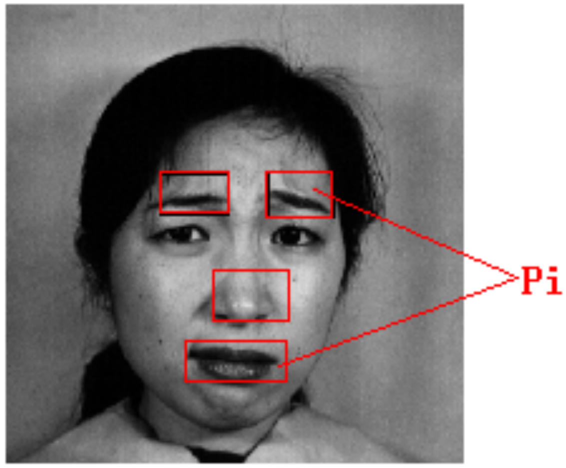

Fig. (3). Sample of combined feature set.

Fig. (**3**) shows the schematic diagram of the combined features. The second part is to use Adaboost to train these feature groups, finding really suitable for feature group of facial expression classification [12]. The main procedure of the algorithm is as follows:

(1) Image capturing and calibration each sample;

(2) Initialize weight value $w_t(t)=1/N$;

(3) For $t=0,\cdots,n$ do;

(4) Running the algorithm 1, identify a set of combined feature;

(5) Training weak classifier h_1, and calculate the error rate c;

(6) Selecting $c1=1/2\frac{1-c}{c}$, update $D_i(i)$:

$D_{t+1}(t)=\frac{D_i(i)\exp(-y_i a_i h_i(i))}{Z_i}$, in which Z_t is a normalized variables;

(7) End for;

(8)Output the final classifier:

$$H(x)=\sum_{t}^{T} a_t, h_t(x) \tag{3}$$

After Adaboost training and selection, it can identify the composition characteristics of the facial motor unit.

2.2. Improved Facial Motion Unit Combination Feature Extracting

The improved algorithm uses genetic algorithm to code, and mark the facial organs area effectively, which improves the training speed of sample classification. The feature extraction methods and steps of the improved are as follows [13]:

(1) Image capturing and calibration each sample;

(2) Initialize weight value $w_t(t)=1/N$;

(3) For $t=0,\cdots,n$ do;

(4) Using genetic algorithm to find a set of combined feature, v is facial expressions combined feature, t is cross times, a is the initial feature, based on the immune genetic algorithm it first generates a genetic sequence:

$$\{v_{t-1}, v_{t-1}^1, v_{t-1}^2, \cdots, v_{t-1}^n\}, a_{t-1} \in R \tag{4}$$

The initial vector $\{a_l^1, a_l^2, \cdots, a_l^n\}$ is as the initial chromosome. If each combination feature sequence $\{k_j^1, k_j^2, \cdots, k_j^n\}(j=1,2,\cdots,L)$ is a function of the expected output effect $\psi_i(i=1,2,\cdots,z)$, each composite feature sequence is sorted as follows:

$$\begin{aligned} &eval(\psi_m)=\beta(1-\beta)^{i-1}, \\ &(i=1,2,\cdots,z), 0<\beta<1 \end{aligned} \tag{5}$$

(5) Using immune genetic algorithm to do adaptive training weak classifier of proportional coefficient h_1, and calculating error rate c, as shown in formula (6)

$$b_c=\sum_{m=1}^{c} eval(\psi_m)(c=1,2,\cdots,z) \tag{6}$$

Copying Z chromosome, and do crossover operation on every initial combination characteristics $\{\alpha_e^1, \alpha_e^2, \cdots, \alpha_e^n\}$ and $\{\alpha_f^1, \alpha_f^2, \cdots, \alpha_f^n\}$.

$$\begin{aligned} &\bar{\alpha}_e^j = y\alpha_e^j + (1-y)\alpha_e^j \\ &\bar{\alpha}_f^j = (1-y)\alpha_f^j + y\alpha_f^j, j=1,2,\cdots,n \end{aligned} \tag{7}$$

Where x is a random real numbers, $x \in [0,1]$. Do mutate operation on the combination features, such as shown in formula (8).

$$\{\bar{\alpha}_e^1, \bar{\alpha}_e^2, \cdots, \bar{\alpha}_e^n\} = \{\alpha_e^1, \alpha_e^2, \cdots, \alpha_e^n\} + N \cdot s \tag{8}$$

(6) Doing crossover mutation operation through genetic algorithm $c1 = 1/2\frac{1-c}{c}$, and update $D_i(i)$:

$D_{t+1}(t) = \frac{D_i(i)\exp(-y_i a_i h_i(i))}{Z_i}$, in which Z_t is a normalized variables;

(7) End for.

2.3. Expression Feature Extraction

Extracting the characteristics of local facial motion unit after the genetic algorithm encoding, the specific steps are as follows [14]:

(1) First assume the pixels of the image is $p \times p$, the horizontal line of the eye as a benchmark, moving step of window set to $p/8$ pixel. The initial position of the sub window scanning is $p/8$ in vertical direction, extracting five $\frac{p}{4} \times \frac{p}{4}$ sub windows, constructing sub block set of ocular movement unit, denoted by $\{P_i\}, i = 1,2,3,4,5$, and through the genetic algorithm code it is marked.

(2) Constructing the export department of regional motion unit using the same method of sub blocks set, denoted as $\{Q_i\}, i = 1,2,3,4,5$, and through the genetic algorithm code it is marked.

(3) In order to focus on the horizontal line of mouth and eyes as a benchmark, in the same way it extracts 3 sub windows as sub block set of nose movement area, denoted as $\{W_i\}, i = 1,2,3$, and through the genetic algorithm code it is marked, total of 13 region extraction.

After the extraction of moving unit, combined with the crossover and mutation feature of genetic algorithm, calculating the Haar features of each sub block region using feature template.

3. THE SUPPORTING VECTOR MACHINE EXPRESSION CLASSIFIER

3.1. The Principle of Support Vector Machine

For nonlinear problems, through the nonlinear transform, the training data is transformed into a linear problem in high dimensional space to obtain the optimal classification face [15]. Suppose there is a nonlinear mapping $\Phi : R^d \to H$. Training algorithm uses only a point in a space product, according to the functional theory, if the function satisfies the equation (1), it corresponds to a space inner product.

$$\iint K(x_i, x_j)\psi(x_i)(x)dxdy > 0, \psi(x) \neq 0, \int \psi^2(x) < \infty \tag{9}$$

While the computational complexity is not increased, then the target function becomes：

$$Q(a) = \sum_{i=1}^{n} a_t - \frac{1}{2}\sum_{i,j=1}^{n} a_t, a_j y_i y_j K(x_i x_j) \tag{10}$$

And the corresponding classification function becomes：

$$f(x) = \mathrm{sgn}[\sum_{i=1}^{n} a_i * y_i K(x_i, x) + b*] \tag{11}$$

Formula (11) is the support vector machine. The training sample data is mapped to high dimensional space, so as to achieve the process of linear separating.

3.2. Improved Support Vector Machine Expression Classifier

The essential of support vector machine expression classifier is a two class classifier, but in practice it often needs to solve multi class classification problems, such as the given training set:

$$X = [(x_1, y_1), ..., (x_l, y_l)] \in (x \times y)^l \tag{12}$$

Where $x \in R^d, y = \{1,2,...,N\}$, $i = \{1,2,...,n\}$. For a decision function $f(x): x = R^d \to y$, carry out the following operations: j class as the positive class, the rest of $N-1$ class as the negative class, decision function can be obtained by support vector machine.

$$f^j(x) = \mathrm{sgn}(g^j(x)) \tag{13}$$

$$g^j(x) = \sum_{i=1}^{l} y_i a_i^j K(x, x_i) + b^j \tag{14}$$

Finally according to the multi classification decision function, it can judge that what kind of the test sample belongs to:

$$f(x) = \arg\max_{1 \le i \le n} g^j(x) \tag{15}$$

In order to improve the classification calculation speed, it can improve by the algorithm using cloud calculating collaborative simulation principle. Firstly training set in the solution domain is equidistantly segment. In the time domain $[t_i, t_{i+1}]$, it can build time generalized matrix a_1, a_2, a_3, a_4 and training set generalized matrix b_1, b_2, b_3, b_4. Generalized matrix for each coordination unit can be defined:

$$\begin{cases} \mathrm{M}(m,n) = a_1 + a_2 m + a_3 n + a_4 mn \\ N(m,n) = b_1 + b_2 m + b_3 n + b_4 mn \end{cases} \tag{16}$$

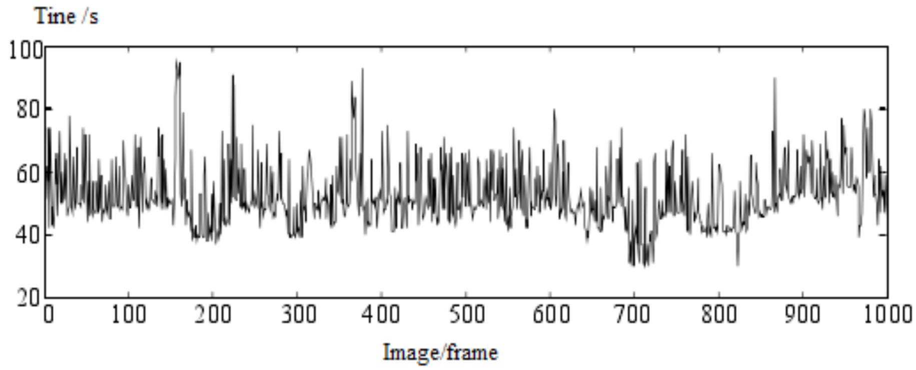

Fig. (4). Real-time test result of face accurate location algorithm.

Assumptions the classification results can be defined:

$$X^T = \begin{bmatrix} x_1 & x_2 & x_3 & x_4 & y_1 & y_2 & y_3 & y_4 \end{bmatrix} \quad (17)$$

Formula (16) and (17) can be written in matrix form:

$$x(m,n) = \alpha a \quad (18)$$

Formula (18) is established for classifying each collaborative simulation, so it can be obtained:

$$\bar{X} = Xa \quad (19)$$

$$H = \begin{bmatrix} \bar{H} & 0 \\ 0 & \bar{H} \end{bmatrix}, \ \bar{H} = \begin{bmatrix} 1 & a_1 & b_1 & a_1 b_1 \\ 1 & a_2 & b_2 & a_2 b_2 \\ 1 & a_3 & b_3 & a_3 b_3 \\ 1 & a_4 & b_4 & a_4 b_4 \end{bmatrix} \quad (20)$$

So the generalized coordinate a is:

$$a = H^{-1}\bar{x} \quad (21)$$

$$H^{-1} = \begin{bmatrix} \bar{H}^{-1} & 0 \\ 0 & \bar{H}^{-1} \end{bmatrix} \quad (22)$$

Classification matrix of computer collaborative computing can be expressed as:

$$S(m,n) = \alpha H^{-1} \quad (23)$$

Through cloud computing collaborative simulation it can effectively improve the training speed of the separator, and make the classifier more powerful.

4. EXPERIMENTAL RESULTS AND ANALYSIS

This paper uses the classical Jaffe face database to carry on the simulation experiment. The database contains 7 types of expression; every kind of expression has some pictures, a total of 213 face images, containing 10 different women images. First, keep one of each expression, and the rest of the pictures are done genetic algorithm coded and as the training sample, then the rest of each expression pictures as test samples, finally using support vector machine classifier to recognize and classify facial expression.

In order to calculate the accuracy rate of recognition, this paper adopts MATLAB programming to carry on the statistics on the recognition results. But MATLAB is strong professional software, in order to improve the easy operation; it uses VB calling method to do visualization. There are many kinds of ways in the VC environment calling MATLAB, now the MATLAB program m files to dynamic link library for the C++ calling, and MATLAB command is: *mcc -t -W lib:libfilename -T link:lib filename*. *libfilename* is a dynamic link library file name from compiler; *filename* is name of m file, and the m file must be a function. After command, *libfilename.lib*, *libfilename.dll* and *libfilename.h* files are obtained, and the main procedures are as follows:

```
x_ba=mean(xi);
y_ba=mean(Y);
F_alpha=input('>>>>>>Input minimum error rate a= ');
while ~(isscalar(F_alpha) && F_alpha<1 && F_alpha>0)
 F_alpha=input('Input training times,   α = ');
end
F_fenweidian=finv(1-F_alpha,k,n-k-1);
c=k/(n-k-1)*F_fenweidian;
if c_flag>c
……
```

This paper selects 800 face images for face recognition test from the image sequence. Firstly it verifies the face location and local characteristics combination coding, and does real-time test experiment on the positioning algorithm, the experimental results are as shown in Fig. (**4**).

It can be seen from Fig. (**4**), the single frame image positioning average consumes only 52.3ms, and it is obvious that this algorithm has better real-time. Through tests on seven kinds of expressions, the results are obtained in Table **1**.

Table 1. Test results of the same individual facial expression recognition success ratio.

	Test 1 /%	Test 2 /%	Test 3 /%	Test 4 /%	Test 5 /%
Anger	91.26	90.02	95.38	94.19	96.25
Happy	96.82	96.81	90.62	89.31	75.22
Neutral	82.82	81.41	80.73	79.07	89.18
Surprised	93.78	89.41	92.13	93.20	89.83
Hate	91.33	93.12	91.18	93.52	94.21
Fear	89.78	85.74	87.02	81.11	89.72
Sadness	80.12	94.92	89.33	93.25	94.10

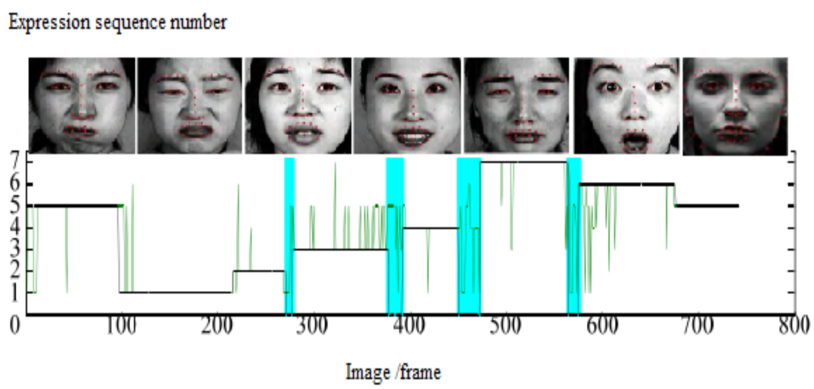

Fig. (5). The average statistical results for the same individual expression recognition.

Table 2. Test results for different individual facial expression recognition success ratio.

	Test 1 /%	Test 2 /%	Test 3 /%	Test 4 /%	Test 5 /%
Anger	91.12	90.32	93.21	94.23	95.22
Happy	97.32	98.13	95.26	97.23	99.25
Neutral	93.13	92.28	91.32	90.23	89.26
Surprised	94.28	92.36	93.13	94.11	93.56
Hate	82.21	83.23	81.19	80.58	82.22%
Fear	86.25	85.78	87.12	85.11	83.71
Sadness	80.13%	80.18	83.12	82.12	83.35

It can be seen from Table **1**, for the same individual expression, 7 basic facial expression recognition rates is higher than 80%, and the system has higher recognition rate on angry, happy, neutral, surprise expression. This is related to the local facial feature, when there is such an expression, the relative position and shape changes obviously for human face sensitive. And hate, fear and grief expressions have lower recognition rate, as the relative position and shape change of face sensitive area is not obvious.

Fig. (**5**) is the average success recognition rate for the same individual basic facial expression. It can be seen from the graph, the system has higher average recognition rate for angry, happy, neutral, surprised than the disgust, fear and sadness, and the results are the same as the test results of monomer.

From Table **2** it can be seen, for different individual expression recognition test, 7 kinds of basic expression

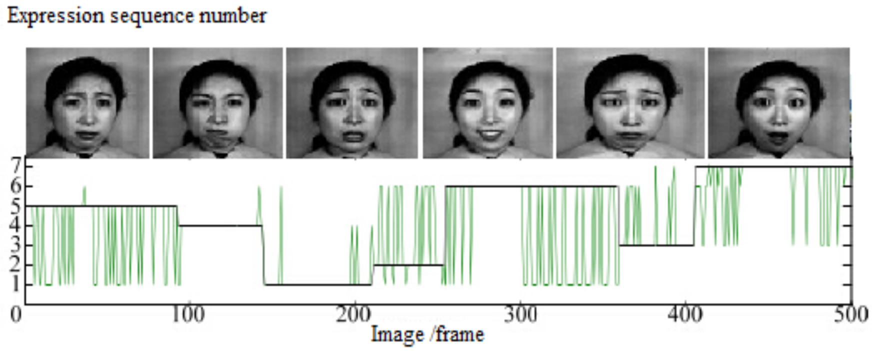

Fig. (6). The average statistical results for the different individual expression recognition.

recognition rate is not less than 80%, and it is the same as the individual test results trend. The system has higher recognition rate on angry, happy, neutral, surprise, and lower recognition rate on disgust, fear and sadness.

Fig. (**6**) is the average recognition success rate for different individual basic expressions. From the figure it can be seen, the system has higher recognition rate for angry, happy, neutral, surprised than the four kinds of expression of disgust, fear and sadness, and the trend is the same as statistics of different individuals, which verified the reliability of the algorithm.

CONCLUSION

This paper uses genetic algorithm to improve extraction method of facial motion unit combining feature, and does genetic algorithm coding on facial organ region, avoiding the error using map feature training, which improves the accuracy of feature extraction. This paper uses cloud calculation collaborative simulation principle to improve the classifier and the training set is done equidistantly segmentation in the solution domain, establishing the generalized matrix of facial local feature, enhancing classification function. Through the testing of the expression database, the improved method has higher recognition ratio on facial expression of different individuals and the same individual, faster calculation speed and better performance.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

ACKNOWLEDGEMENTS

Declared none.

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Received: September 16, 2014 Revised: December 23, 2014 Accepted: December 31, 2014