Multi-Pose Face Recognition Using Fuzzy Ant Algorithm and Center of Gravity Search

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Summary
In this paper, we present the novel technique to solve the recognition errors and minimize memory size of invariant range image multi-pose face recognition. Range image face data (RIFD) was obtained from a laser range finder and was used in the model to generate multi-pose. The fuzzy ant clustering algorithm is used to classify and find the number of clusters for reduced recognition time. RIFD will be transformed by the gradient transformation into significant feature and matching by using Membership Matching Score (MMS) and Center of Gravity (CG) search. The proposed method was tested using facial range images from 130 persons with normal facial expressions. The processing time of the recognition system is better than 3LMS. Moreover, it is 6 times faster without any change of recognition rate. Memory size of this experimental was about 136,890 bytes which show that the memory sizes decrease to extremely small-scale knowledge base.

Key words
Face Recognition, Fuzzy Ant Clustering, Center of Gravity Search

1. Introduction

Nowadays, a security system is essential to our lives since more criminals are being committed. One part of the security and authorization system which is very popular due to its simplicity is personal code recognition. However, the problems of password forgotten and stealing are the consequences of its simplicity.

Biometric research involves the retrieval of biometric identities such as iris, fingerprints, or face pictures. The use of iris and fingerprint is limited since the necessity of the direct physical contact between human and devices which causes latency and inconvenience of operations. On the other hand, human face recognition using verification of face photos taken by cameras is not restricted by such limitation.

Accordingly, human face recognition is considered interesting [1]-[3] as it is one of the alternative that mostly related with 2 dimensional face pictures. The problem of light and positions inconsistencies of each face shot may occur if the 2 dimensional face to face is being used in face recognition. This leads the recognition difficulties. The 3 dimensional face recognition use face surface data as the third dimension for it could help reducing the light adjustment, and face positioning problem [4]-[6]. Nevertheless, this method needs more techniques and auxiliary equipment for measuring face depth and storing data in 3-dimension. Zhang T. [7] uses Gradient Face to extract illumination insensitive features for face recognition under varying lighting.

Pansang S. [8] had studied face recognition by use of RIFD. This approach can solve both the problems of size and pose error by setting a new pose in order to be being matched with an unknown face pose data in accordance with geometric transform usage. Nevertheless, a flaw of this procedure is there are a large number of pose positions to be calculated. It is because the recognition system does not know the pose position of unknown face. The 3-Layer Matching Search (3LMS) approach is an approach that can reduce laborious works of the pose position calculation. It requires 57 comparisons to covering all 625 sets of pose images of one person.

However, the use of CG search approach could help searching pose position better than 3LMS by the speeding up to 6 times and ant based clustering has the ability of automatically discovering the number of clusters and fuzzy c-means is used on the clusters formed by the ants. This approach could also help searching person's position in database cluster more rapidly.

2. OVERVIEW OF THE SYSTEM

The overview of the face recognition system is illustrated in Figure 1. There are two procedures in this system; Registration and Recognition. In the registration procedure, the faces of each tested subject that the system is required to acknowledge are added to the RIFD database. The human face is digitized into the range image database by using the laser range finder [8]. The size is adjusted to 156 × 108 pixels with a range resolution of ± 1 mm. The region of RIFD covers the area of about 240 × 166 mm2. This face size is the average for most Asian people.

Since acquisition process, scale and center are varied each time and difficult to be controlled which directly affects the recognition rate. It is necessary to normalization for adjusting the parameters of all RIFD to meet the standard values, reduce image size, gradient transform and re-pose calculation① to covering pose variation region ±24°

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up/down and left/right (UDLR) from initial pose. The Ant based has discovering the number of clusters and Fuzzy c-means is used on the clusters formed by the ant②. In this case, the RIFD will be collected in database④ for which each cluster will have individual agent as a delegate③.
In the recognition procedure, unknown gradient face need to extracted face feature similar to the registration procedure. RIFD will be confined Rough group⑥. This data will be used as inputs of matching and searching process⑦. The result of this process will be used to open table⑨ for showing identification name of unknown face⑧.

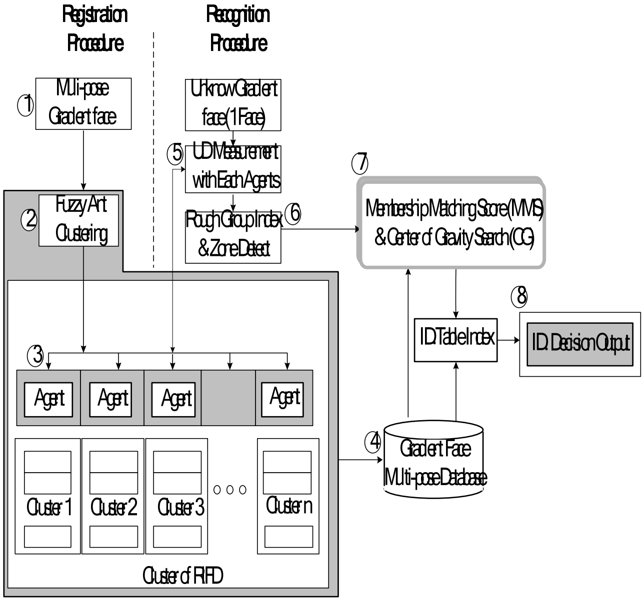


Fig. 1 Overview the system

3. REGISTRATION PROCEDURE

3.1) Multi-pose Gradient Face

The gradient faces are the results of separating the defining features from the image of the face. This is done by calculating the slope or gradient at each point on the surface of the face against its surrounding area. Using partial derivative to find the gradient phase along axis X and Y called a matrix phase image f(x,y) at position (x,y) as shown in equation (1).

$$G_x = \frac{\partial f}{\partial x}, G_y = \frac{\partial f}{\partial y} \qquad (1)$$

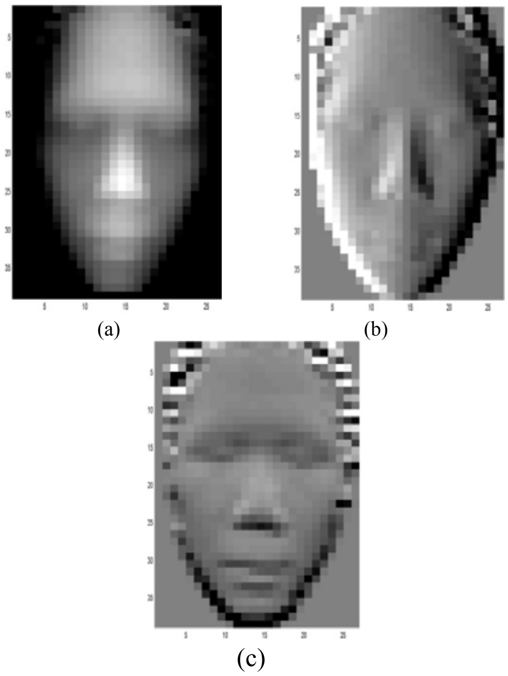


Fig. 2 gradient face obtained from conversion of a face image

(a) Face Image before conversion, with a dimension of 39×27

(b) Image after conversion to gradient phase Gx

(c) Image after conversion to gradient phase Gy

The synthetic generation of facial data for varying perspectives both in the Azimuth and Lift angle to encompass all scope of use. The perspective range for facial data is between ±24 degrees, as shown in Figure 3. The angles generated include tilt up – down and turn left – right. Alteration of the face data to coordinates of each view were done by using Geometric Transform and changing the angle by 2 degrees each, reducing the number of perspectives is reduced to 25 for tilt up - down and 25 for turn left - right. Therefore there will be 625 of various angles used in this experiment for each face image.

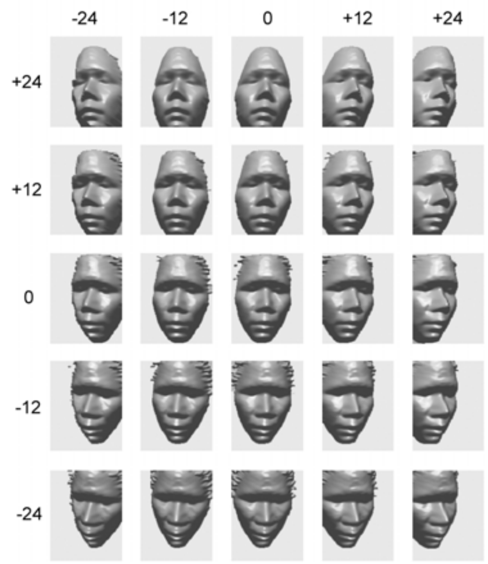


Fig. 3 (a) The perspective of each pose that the system is able to recognize within the angle range of ±24, displayed in steps of 12 degrees per pose.

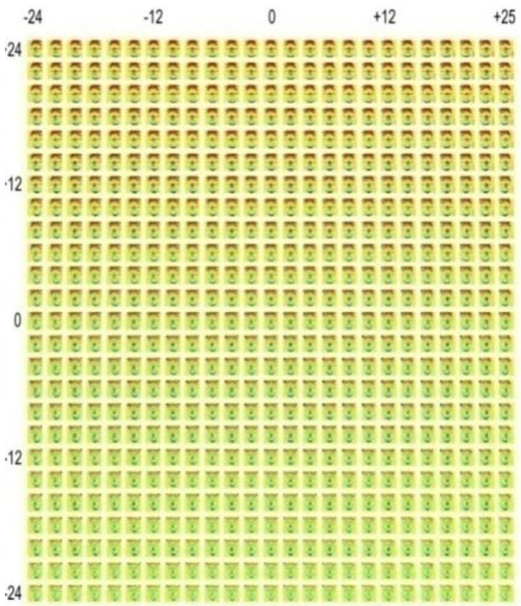


Fig 3. (b) The 625 poses of one face image used in the experiment.

3.2) CG of RIFD

Since the RIFD is based on 3-D graphic data, the change of plane surface distance data will vary in accordance with the changed pose. Consequently, the center of gravity of RIFD can be used as an indicator of pose position of RIFD, approximately. This can be consecutively applied to adjust pose position of RIFD which is brought in the registration procedure, correctly. And these could be beneficial for prediction pose position zone of unknown RIFD in registration procedure, roughly. As a result, searching pose position for matching with unknown face will be carried out more rapidly. The vicinity of RIFD image for searching CG position can be solved from equation (2) to (5).

$$InterestingPos = \left\{ Z_{(i,j)} \middle| Z_{(i,j)} \geq \frac{Z_{\max}}{\sqrt{2}} \right\} \quad (2)$$

InterestingPos is data point coordinate of RIFD that the value of $Z_{(i,j)}$ when $Z_{(i,j)} \geq$ root mean square (RMS) of $Z_{\max}$, $Z_{(i,j)}$ = the range value from base plane to face surface of RIFD, $Z_{\max}$ = maximum value of RIFD. Interest poses position images is shown as Figure 4(b).

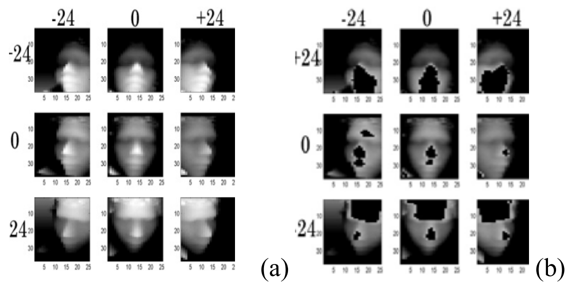


Fig.4 Multi-pose RIFD images

RMS of $Z_{\max}$ is an appropriate threshold for distinguish interesting surface from face surface same RMS in electronic field. Then, the interesting area for searching CG can be described in equation (3).

$$InterestingArea = i_{\min} \text{ to } i_{\max}, j_{\min} \text{ to } j_{\max} \Big| Z_{(i,j)} \geq \frac{Z_{\max}}{\sqrt{2}} \quad (3)$$

The position of interesting area start from $i_{\min}$ to $i_{\max}$ and $j_{\min}$ to $j_{\max}$, when i and j are coordinate of Z only for $Z_{(i,j)} \geq$ RMS of $Z_{\max}$.

Hence,

$$CGx = r \left| \sum_{j=j_{\min}}^{r} \sum_{i=i_{\min}}^{i_{\max}} Z_{(i,j)} = \frac{1}{2} \sum_{j=j_{\min}}^{j_{\max}} \sum_{i=i_{\min}}^{i_{\max}} Z_{(i,j)} \right. \quad (4)$$

$$CGy = c \left| \sum_{i=i_{\min}}^{c} \sum_{j=j_{\min}}^{j_{\max}} Z_{(i,j)} = \frac{1}{2} \sum_{i=i_{\min}}^{i_{\max}} \sum_{j=j_{\min}}^{j_{\max}} Z_{(i,j)} \right. \quad (5)$$

Equation (4) and (5) are used to find the CG coordinate (CGx, CGy) of interesting area. When r is the position between imin to imax, while summation of Z(i,j) in row of interesting area is equal to half of all in row. And c is considered same with r but it's in term of column. The result of this equation is shown in fig.5.

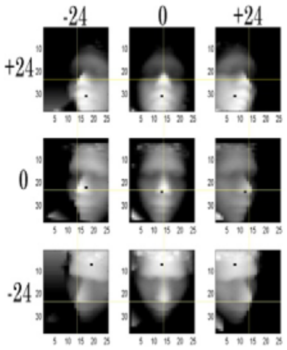


Fig.5 RIFD pose position, black points on each RIFD image shown the CG position.

3.3) Fuzzy Ant Clustering

- *Ant base clustering algorithm*

In using Ant base clustering to divide groups it is assumed that Ant is separated on a 2 dimensional board, this board can consider matrix C of cell m × n. The dimension of the board depends on the number of object, in this case a board measuring m × m or $m^2 = 4n$. At the beginning Ant will be distributed randomly along on the board with $\frac{n}{3}$ Ant where n is the total number of Object to be divided into groups.

Heap is a collection of Object 2 Object or those that exceed Ant and dividing Object from Heap. The parameter for Heap will be limited as follows

(1) the largest distance between the Object and the equation.

$$D_{\max}(H) = \max_{O_j, O_j \in H} D(O_i, O_j)$$

Where $D_{\max}(H)$ is the largest distance between 2 dimensional Object within Heap.

$D(O_i, O_j)$ is finding the Euclidian distance between Objects

(2) Finding the Center of a group in Heap using equations

$$O_{center}(H) = \frac{1}{n_H} \sum_{O_i \in H} O_i$$

Where $O_{center}(H)$ is the Center of the group of every object in the Heap.

(3) Finding $O_{dissim}(H)$ the object furthest from the center of the Heap.

(4) Finding the average distance between object of H and the center of the Heap group using the equation

$$D_{mean}(H) = \frac{1}{n_H} \sum_{O_i \in H} D(O_i, O_{center}(H))$$

Where $D_{mean}(H)$ is the average distance between Object of heap and the center of the group.

- *Fuzzy c- means*

Fuzzy c-mean will be used after Ant base clustering had obtained an initial number of groups.

(1) From RIFD database, we can define a family of fuzzy partition matrix , M_{fc}, for the classification involving c classes and n data points,

$$M_{fc} = \left\{ U_{cxn}^{(0)} \mid u_{ik} \in [0,1]; \sum_{i=1}^{c} u_{ik} = 1; 0 < \sum_{k=1}^{n} u_{ik} < n \right\}$$

Where i=1,2, …, c; k = 1,2, …, n and $U_{cxn}^{(0)}$ is a fuzzy c – partition (n data points, c classes) from the each pose of n face images. We fix c ($2 \leq c \leq n$) and initialize the U matrix:

$U_{cxn}^{(0)} \in M_{fc}$. Each step in this algorithm will be labeled r, where r = 1,2,…

(2) Crate the data matrix in each pose, $X_{n \times z}$, so that it has z elements from each pose of n face images.

(3) Calculate the c center:

$$V_{ij} = \frac{\sum_{k=1}^{n} u_{ik}^{m'} . X_{kj}}{\sum_{k=1}^{n} u_{ik}^{m'}}$$

Where j = 1,2,…,m

m is a weighting parameter to control the amount of fuzziness in the classification process.

(4) Calculate d_{ik}:

$$d_{ik} = d(x_k - v_i) = \left[\sum (x_{kj} - v_{ij})^2\right]^{1/2}$$

Where u_{ik} is the membership of the k th data point in the i th class.

(5) Update the partition matrix for the r th step, U (r) as follows:

$$u_{ik}^{(r+1)} = \left[\sum_{j=1}^{c}\left(\frac{d_{ik}^{(r)}}{d_{jk}^{(r)}}\right)^{2/(m'-1)}\right]^{-1} \quad \text{for } i_k = \varnothing$$

Or

$u_{ik}^{r+1} = 0$ for all classes i where i $\in I_k$

Where

$I_k = \{ I \mid 2 \le c \ge n ;\ d_{ik}^{r} = 0$

And

$$\widetilde{I}_k = \{1,2,...,c\} - I_k$$

And

$$\sum_{i \in I_k} \mu_{ik}^{(r+l)} = 1$$

(6) If $\| U(r+1) - U(r) \| \le \varepsilon L$, stop ; otherwise set r = r+1 and return to step (3).

Fuzzy Ant Clustering

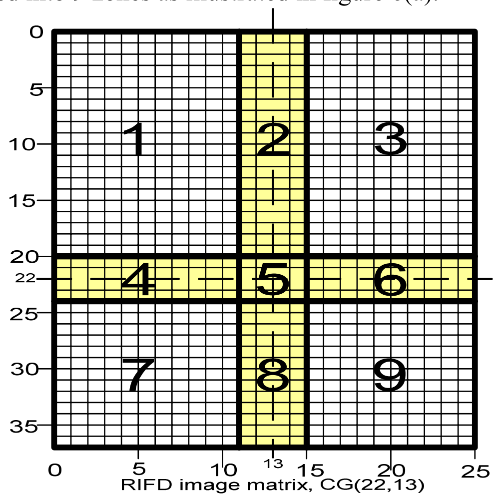
(1) Scatter the objects randomly on the board
(2) Initialize the ants with random position, and random direction
(3) for 1000 interaction Do
3.1 For each ant Do
3.1.1 Move the ant
3.1.2 If the ant is carrying an object i then possibly drop the object i else
3.1.3 Possibly pick up an object i
(4) Use the cluster centers obtained in step 3 to initialize cluster centers for the Fuzzy c-means algorithm
(5) Cluster the data using the fuzzy c-means algorithm
(6) Harden the data obtained from the fuzzy c-means algorithm, using the maximum membership criterion, to form new heaps
(7) Repeat step 1-6 by considering each heap as single

4. RECOGNITION PROCEDURE

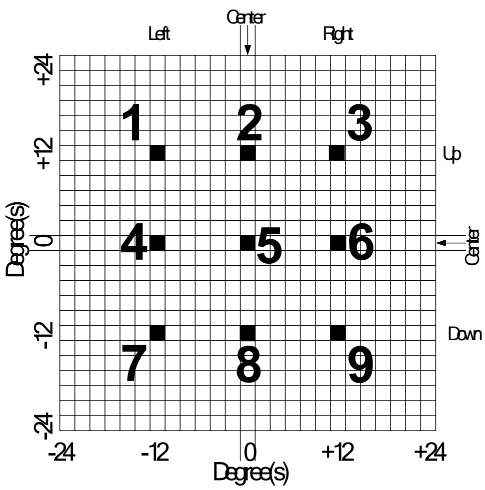
The facial recognition procedure is the processing of data through a method to see whether the owner of the facial data match anyone within the database. This is done by matching the facial data of the subject to reference data within the database. The highest similarity rating will point to the owner of the facial data.

4.1) Center of Gravity Search (CG Search)

This matching approach is developed from 3LMS [8]. The CG search composed of 3 layers, the same as with 3LMS. Nevertheless, they are different by the given center point (R1, C1) of matching position in layer 1. The approach for finding CG of RIFD is used for stipulating zone of matching point position. From figure 6, RIFD will be divided into 9 zones as illustrated in figure 6(a).



(a)



(b)

Fig. 6 Relation between CG of RIFD and multi-pose variation image matrix

a) CG zone image mapping of RIFD

b) Center position (R1, C1) of matching region (black).

From figure 6(a), RIFD will be divided into 9 zones of which are calculated for the CG position of unknown RIFD. Whether zone is the CG position in, we can specify (R1, C1) values due to Table 1, figure 6(b). The regions of the multi-pose image matrix that the system can acknowledge in this experiment, contains a size of ±24º UDLR, at 2 degrees/pose and is arranged in a 25x25 pose image matrix. The black block show position (R1, C1) of which is transferred from the CG position value according to Table Define: RIFD matrix size is 37×25, Standard of reference CG position as (22, 13), (R1, C1) is a center point of matching position in layer 1.

Table 1: Relation between zone and (R1, C1)

CG Position	ZONE	(R1,C1)
(0to22,0to10)	1	+12,-12
(0to22,11to15)	2	+12,0
(0to22,16to25)	3	+12,+12
(20to24,0to10)	4	+12,-12
(20to24,11to15)	5	0,0
(20to24,16to25)	6	+12,-12
(25to37,0to10)	7	-12,-12
(25to37,11to15)	8	0,-12
(25to37,16to25)	9	-12,+12

4.2) Membership Matching Score (MMS)

The MMS is the technique that enables the model to efficiently classify the differences of the surface slope of RIFD. This technique is based on image base matching, which is quite simple, requiring a small image size. Surprisingly, MMS shows a high correction rate result compared with conventional matching methods, due to the requirement that the conventional method uses a larger image size. The MMS special characters can be used to match numerous poses in the multi-pose database.

Additionally, the MMS method calculates the similarities between two data sets. This MMS method is voting by counting number of the memberships in the inner boundary. Voting score is used as the indicator to measure the similarity level. Using the gradient of RIFD results in more accurate classification, and this characteristic of the gradient of RIFD is suitable for the MMS method. The results are better than using normal RIFD, which is not a pure feature. The region between the upper and lower boundary can be seen in Eq.(6).

Define:

$$\overline{f(x_i,y_i)} = f(x_i,y_i)\lfloor f(x_i,y_i) > f^r(x_i,y_i) + \zeta \rfloor$$

$$\underline{f(x_i,y_i)} = f(x_i,y_i)\lfloor f(x_i,y_i) > f^r(x_i,y_i) - \zeta \rfloor$$

$$\underline{\overline{f(x_i,y_i)}} = \sim \overline{f^r(x_i,y_i)} \cap \sim \underline{f^r(x_i,y_i)} \qquad (6)$$

and n{A} = number of numbers in set A, then score of Membership on inner boundary (similarity score) is shown as the following equation:

$$M = n\left\{ f^t_{(x_i,y_i)} \cap \underline{\overline{f(x_i,y_i)}} \,\middle|\, f^t_{(x_i,y_i)} \in E \wedge f^t_{(x_i,y_i)} \neq 0 \right\} \qquad (7)$$

Notation:

$\overline{f(x_i,y_i)}$ = Upper Boundary area.

$\underline{f(x_i,y_i)}$ = Lower Boundary area.

$\underline{\overline{f(x_i,y_i)}}$ = Area between Upper and Lower Boundary.

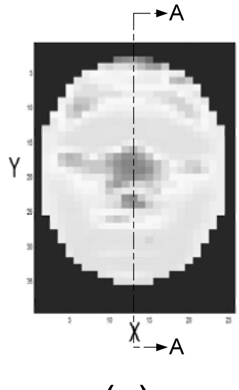
ζ = gap distance

E = position in elliptic mask boundary
n = number of element in ellipse area
M = number of members in inner boundary
x, y = column and row of image matrix and
i = 1 to 156, j = 1 to 108.

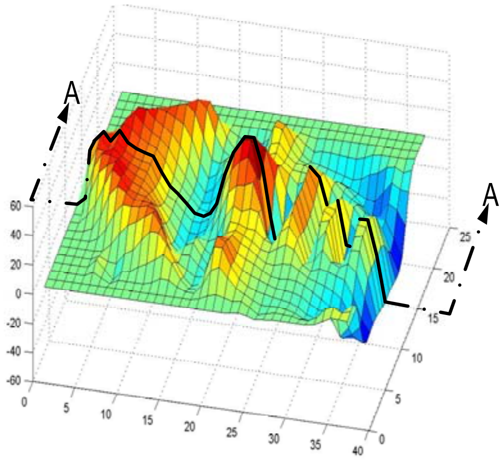
$f^r(x_i,y_i)$ is the mean function of reference face, which comprises of the vector of gradient RIFD at the position x_i,y_j of any person number (i) and pose (j).

$f^t(x_i,y_i)$ is the mean function of test face, which comprises the vector of gradient RIFD at the x_i,y_j position for any person number (i) and pose (j). Details of above variables can be illustrated in Fig 7(a)-(c).

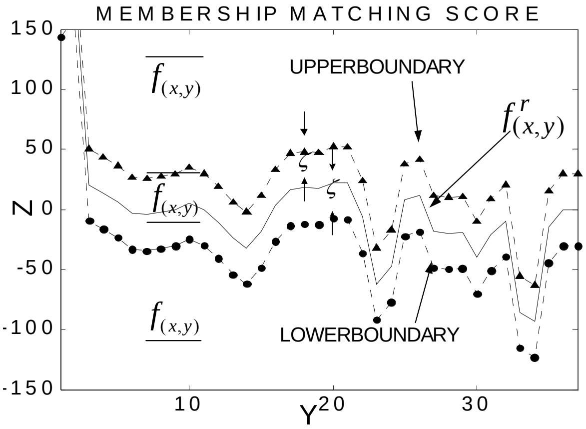
This figure shows the function $f^r(x_i,y_i)$ with upper boundary $\overline{f(x_i,y_i)}$ and lower boundary $\underline{f(x_i,y_i)}$.



(a)



(b)



(c)

Fig. 7 Function with Upper boundary and Lower boundary
(a) and (b) Gradient face line A – A and plot in (c)

Referring to Eq. (7), M shows the score of similarity surface of two data sets. Thus, the similarity level can be calculated by Eq. (8).

$$\text{Similarity} = \frac{M}{N} \qquad (8)$$

From Eq.(8), when similarity moves toward the number one, this shows the test gradient image and reference image are behaving accordingly. A maximum peak of pose similarity in each record is used to determine the maximum peak for each test subject. This determination can classify an individual test subject, which can then be explained by Eq.(9)

$$\text{Personal Index} = \max(\text{Similarity}(i,j)) \qquad (9)$$

Where i and j are index similarity of persons (records) and poses (fields) sequence respectively. The field number is the number of generated multi-pose for each test subject. The record number is the number of the test subject that is assigned for face recognition. The altered characteristic of pose (j) gradually changes for every 2 degrees. Thus, the matching search process does not necessarily do the matching for each pose.

6. EXPERIMENTAL RESULTS

6.1) RIFD Feature grouping

Canonical of RIFD from 130 face-sampling are used in the experiment. For which RIFD is normalized for finding CG and roughly grouping. Then they are brought to grouping by Fuzzy ant clustering. In the experiment, the system can be grouped for 4 in number. By which each group will have 27-33 members. As a result, searching for unknown RIFD appropriate for whatever the group will be operated not more than 4 times only. In each group will have not more than 33 members and the said member will be collected in the list for reference data in matching process.

6.2) Multi pose face recognition test

Because of a large number of data consisted; reference personal data (130 persons), pose data of each person (625 poses), all data matching cannot be practically carried out by linear matching method. The reason is it must be operated 81,250 matching for 1 recognition test whereas 3 LMS [8] uses matching 59×130=7,760 times. CG search approach can reduce a lot of matching search times for using option variables "rough group index and zone detect" (see figure 1. block number⑦) in fostering index person in database. Number of matching times can be found from (number of searching group(4) + RIFD CG-search 1 matching + (number of searching time in layer 2 and 3, 34 matching × number of persons in a group consisting highest number of the members (33)) only 1,127 matching. It is faster than 3LMS 6 times. Table 2 shows the comparison of recognition results. In each method, the percentage of recognition for which the best result was fuzzy ant clustering in clustering approach, MMS and CG search in matching approach.

Table 2: Show the comparison of recognition rates.

Matching Approaches	Clustering Approaches	Time Average/person	Recognition rates (%)
MMS + 3LMS	-	6.480 Sec	95.67
MMS	K-means	4.875 Sec	86.75
MMS	c-Means	0.120 Sec	90.82
MMS + CG search	Fuzzy Ant Clustering	0.050 Sec	95.45

7. CONCLUSION

The face recognition systems, which employs multi-poses face image from 130 people in the recognition process, has been proven to be highly successful. This study used the integration of Fuzzy Ant clustering algorithm into the classification technique of the invariant range image multi-poses face recognition process. The experimental confirms that fuzzy ant clustering is better than k-means for classifying the face surface and CG search is better than 3LMS.

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