Invariant Range Image Multi-pose Face Recognition Using K-means, Membership Matching Score and Center of Gravity search

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Abstract: In this paper, we propose the method to search the appropriate pose position for matching in invariant range image multi-pose face recognition system. The center of gravity search is used for searching pose position in range image face database (RIFD). Reference persons database are grouped by using K-means cluster for speed up processing time. This approach is developed for implementation the invariant range image multi-pose face recognition system. This face recognition system is created to function covering pose variation region ±24 degrees up/down and left/right (UDLR) from initial pose. RIFD used in this face recognition is based on 3-D Graphics database. For this advantage, we could solve scale, center and pose error problem by using geometric transform. RIFD that is obtained from range image sensors will be used for operation by reducing data size. RIFD will be transformed by the gradient transform into significant feature and matching by using membership matching score. The proposed method was tested using facial range images from 130 persons with normal facial expressions. The processing time of the recognition system has to be better than 3LMS by the speeding up to 10 times without any change of recognition rate.

Keywords: Face recognition, Face range image, Laser scan, Geometric transformation, Center of Gravity and K-means.

1 Introduction

Nowadays there are a lot public service organizations those need effective personal identification techniques for servicing a large number of people comfortably and fastly. Taking face recognition system for use in the organization is the best way. By this technique, the person being identified knows nothing about the process, no touching, no staring or even none of any activity related to sensor instrument. Face recognition research is a very challenging task for having a lot of uncontrollable variables. The researchers has a great difficulty with two major problems. Firstly, technical problems involves the problems that generated from the light source, the pose variation, and shooting distance that related to scale and center of image. This first group of problems is the variables those are difficult to control. The second problem is the face variation; the examples of this are facial expressions, action, aging, eye-glasses, posture, hairstyle, moustache and beard. The face recognition from RIFD is a very interesting topic due to its three dimensions range data characteristics. This type of data is more difficult to be altered or to be disguised, but it still can be helped solving the technical and the face variation problem better than 2-D image base. Currently, RIFD input machine has effectively created; therefore there is the potential for 3-D face recognition system by using the range image data.

Various related researches has indicated that most face recognition systems focus on a single pose [1-4]. Pose variation problems occur in single pose face recognition models when the pose position of the tested face was changed from the pose database value. Furthermore, single pose face recognition has not worked
flexibly with variation of pose in the past and continues to be a problem. Face recognition by use of RIFD is an interesting procedure. For we 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 an unknown face. The 3-layer matching search approach [5] is an approach that can reduce laborious works of the pose position calculation. It requires only 57 times (9.44%) to covering all 625 sets of pose images of one person. However, the use of CG search approach could help searching pose position and K-means approach could also help searching person’s position in database cluster more rapidly.

2 Data Acquisition
What is Range Image Face Data (RIFD)? It is a range data of faces in rectangular form, x and y are co-ordinate, and then \( Z(x, y) \) is ranged from base plane to face surface at \( x, y \) co-ordinate. The advantage of rectangular form is very easy for calculation.

![Fig.1 Range Image Face Data and a laser range finder](image1)

The human face is digitized into the range image data by using the laser range finder [10]. The size is adjusted to 156 ×108 pixels with a range resolution of ±1mm. The region of RIFD covers the area of about 240×166 sq.mm. This face size is the average for most Asian people.

![Fig.2 RIFD for use in the process](image2)

Digitized RIFD is used as a model to generate multi-pose RIFD by using geometric transform. Linear reduction is used for reduction of each pose image data size. Gradient Transform is used in extracting features from the data. The data is reduced again by ellipse face region extraction [9] and finally the features are stored in a multi-pose database.

3 Overview of the System
The overview of the face recognition system is illustrated in Figure3. 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 data by using the laser range finder [10]. The size is adjusted to 156 ×108 pixels with a range resolution of ±1mm. The region of RIFD covers the area of about 240×166 sq.mm. This face size is the average for most Asian people.

![Fig.3 Overview of the face recognition system](image3)
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 \( \dagger \) for adjusting the parameters of all RIFD to meet the standard values. After having carried out the normalization, RIFD will be searched for the center of gravity and the pose will be scrutinizingly fine-adjusted to the standard point \( \ddagger \) and arranged RIFD clustered by K-means clustering \( \ddagger \). In this case, the RIFD will be collected in database \( \ddagger \) for which each cluster will have individual agent as a delegate. After that the data inside cluster of RIFD \( \ddagger \) will be taken to re-post calculation. It is created to function covering pose variation region \( \pm 24 \) degrees up/down and left/right (UDLR) from initial pose\( \ddagger \), reduce image size\( \ddagger \), gradient transform\( \ddagger \) for extracting face feature, extract only ellipse face area\( \ddagger \) and sent to keep in Gradient Face Multi-pose Database\( \ddagger \). It is clearly comprehended that single pose data in the block of cluster of RIFD \( \ddagger \) will be taken to Multi pose at gradient face multi-pose database\( \ddagger \).

In the recognition procedure, RIFD unknown face will be normalized similar to the registration procedure. After that the data will be divided into 2 parts. The first will be sent for evaluating the center of gravity and fine adjusted pose to standard point \( \ddagger \) in matching for data cluster searching and a delegate of cluster of RIFD in block number 4. The second RIFD unknown face will be reduced by size, extracted face feature and region in block number 15,16, and 17, respectively. The evaluated CG of RIFD will be confined in Zone at block number 14. These data will be used as inputs of matching and searching process in block number 18. The result of this process will be used to open table for showing identification name of unknown face in block diagram number 20.

4 Registration Procedure

4.1 Normalization

Scale and center from the camera occurs from digital capture of the object at various distances. Size error is solved by calculating the scale index, which is the relationship between the ratio of the frame size and the face size [11], the camera view angle, and the constant ratio of the standard distance, as described in Ref. 5, 12. Center of RIFD is the nose tip, its must be the defined position of the RIFD frame, which is then transferred into the standard assigned position of the frame. This method is necessary due to its accuracy for data analysis. Center adjustment transferring is calculated by geometric transform equation [13-14].

4.2 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 (1) to (3).

\[
\text{InterestingPos} = \left\{ \frac{Z_{(i,j)}}{Z_{(i,j)}} \geq \frac{Z_{\text{max}}}{\sqrt{2}} \right\} \tag{1}
\]

\( \text{InterestingPos} \) is data point coordinate of RIFD that the value of \( Z_{(i,j)} \) when \( Z_{(i,j)} \geq \sqrt{2} \) the range value from base plane to face surface of RIFD, \( Z_{\text{max}} = \) maximum value of RIFD. Interest pose position images is shown as Figure 4(b).
Fig. 4 Multi-pose RIFD images
(a) Gray lever images of multi-pose RIFD. (b) Interesting pose position (From equation 1.)

RMS of $Z_{\text{max}}$ is an appropriate threshold for distinguishing interesting surface from face surface same RMS in electronic field. Then, the interesting area for searching CG can be described in equation 2.

$$\text{Interesting Area} = i_{\text{min}} \text{ to } i_{\text{max}}, j_{\text{min}} \text{ to } j_{\text{max}} \left| Z_{(i,j)} \geq \frac{Z_{\text{max}}}{\sqrt{2}} \right. \quad (2)$$

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

Hence,

$$CG_x = r \sum_{i=i_{\text{min}}}^{i_{\text{max}}} \sum_{j=j_{\text{min}}}^{j_{\text{max}}} Z_{(i,j)} = \frac{1}{2} \sum_{i=i_{\text{min}}}^{i_{\text{max}}} \sum_{j=j_{\text{min}}}^{j_{\text{max}}} Z_{(i,j)} \quad (3)$$

$$CG_y = c \sum_{i=i_{\text{min}}}^{i_{\text{max}}} \sum_{j=j_{\text{min}}}^{j_{\text{max}}} Z_{(i,j)} = \frac{1}{2} \sum_{i=i_{\text{min}}}^{i_{\text{max}}} \sum_{j=j_{\text{min}}}^{j_{\text{max}}} Z_{(i,j)} \quad (4)$$

Equation 3 and 4 are used to find the CG coordinate ($CG_x$, $CG_y$) of interesting area. When $r$ is the position between $i_{\text{min}}$ to $i_{\text{max}}$, 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 $r$ it’s in term of column. The result of this equation is shown in fig. 5. Since RIFD reference in registration procedure are grabbing with normal position and it is uneasy to control each acquisitions RIFD to be in correct pose position and the same pose position every time and everyone. Consequently, it is essential to specify the CG point of standardized RIFD in order to be used as a reference point of every entering acquired RIFD. Nevertheless, according to various experiments it was found that each input RIFD data will have little change in pose position. The adjust of RIFD pose position to standard pose position will contribute more correct data. The RIFD of each input person will be searched for center of gravity position and transformed by geometric transform in order to adjust the CG value closest to the reference CG. This will process the RIFD of every face having the same standard CG position to classify face characteristics by K-mean clustering, consecutively.

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

4.3 K-means clustering
K-means clustering is a method of classifying data clusters in order to increase speed of data identification which is widely used in general recognition system. The K-means [15] clustering is for data clustering of similar feature to be in the same cluster. Each cluster will have a mean value of delegated feature. If the excess number of different features is more than the given threshold values, a new cluster will be managed. Measurement of similar level of various feature will be carried out by Euclidean distance (UD). The distance between Set#1 and Set#2 feature data is measured in the process in which can be described by equation 5 to 7 and lower algorithm.

Given,

$$f_{(a)} = [a_1, a_2, ..., a_n] \quad (5)$$

$$f_{(b)} = [b_1, b_2, ..., b_n] \quad (6)$$
In line number 9 if UD calculated by Eq.8 is in accordance with threshold number of face will be sent to member in Mgroup number (k), f-mean (k) is the feature agent group. And a new group will be created when the UD calculated by Eq.8 is not accordance with all of groups, the value of feature f(n) will be used as f-mean of the group previously. Because of having only one member and will be used for comparison with UD in the next cycle. When the procedure is achieved, Mgroup will have group member equal to added group. Each group will consist of members having corresponding features. To find whether the unknown feature is in accordance with any data group, only finding UD value and agent feature of each group, the group having the lowest UD value will be selected for matching. By the way, it will help more rapid matching process because of no need to matching with all groups of data.

5 Recognition Procedures

This procedure consists of various block diagrams. Its details are in Ref. number 5.
So, in this paper the researcher will describe the added parts. It is for improvement of the effectiveness of job. The objectives of this paper is to focus on two points; application of K-mean clustering and CG Matching Search (CGMS) in order to increase pose and person searching velocity for matching process.

5.1 CG Matching search
This matching approach is developed from 3 Layer Matching Search (3LMS) [5]. CGMS compose 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 in item 4.2 is used for stipulating zone of matching point position. From fig.6, RIFD will be divided into 9 zones as illustrated in fig. 6(a).

(a) CG zone image mapping of RIFD
(b) Center position (R1,C1) of matching region (black block).
From fig. 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, fig.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>
<thead>
<tr>
<th>ZONE</th>
<th>(R1,C1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0to22,0to10</td>
<td>1, +12,-12</td>
</tr>
<tr>
<td>0to22,11to15</td>
<td>2, +12,0</td>
</tr>
<tr>
<td>0to22,16to25</td>
<td>3, +12,+12</td>
</tr>
<tr>
<td>20to24,0to10</td>
<td>4, +12,-12</td>
</tr>
<tr>
<td>20to24,11to15</td>
<td>5, 0,0</td>
</tr>
<tr>
<td>20to24,16to25</td>
<td>6, +12,-12</td>
</tr>
<tr>
<td>25to37,0to10</td>
<td>7, -12,-12</td>
</tr>
<tr>
<td>25to37,11to15</td>
<td>8, 0,-12</td>
</tr>
<tr>
<td>25to37,16to25</td>
<td>9, -12,+12</td>
</tr>
</tbody>
</table>

Table 1 Relation between zone and (R1,C1)

6 Experimental and Results

6.1 RIFD Feature grouping
Normal pose 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 means of K-mean clustering. In the experiment, threshold=0.3 is specified, the system can be grouped for 27 in number. By which each group will have 2-21 members. As a result, searching for unknown RIFD appropriate for whatever the group will be operated not more than 27 times only. In each group will have not more than 21 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; ref. 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 times for 1 recognition test whereas 3 LMS [5] uses matching 59×130=7,760 times. CGMS approach can reduce a lot of matching search times for using option variables “rough group index” from item 4.3 and “zone detect” from item 4.2 (see figure 3. block number 13,14) in fostering index person in database. Number of matching times can be found from (number of searching group(27)+ RIFD CG-search 1 time+ (number of searching time in layer 2 and 3, 34 times x number of persons in a group consisting highest number of the members (21)) only 742 times. It is faster than 3LMS 10 times.

7 Conclusion
Grouping the RIFD with similar features by means of K-mean clustering helps rejecting large number of non-corresponded data from matching process. For, group searching in K-mean cluster is carried out by use of distant picture data which can be only executed roughly. It could not be processed in personal details and pose position. As a result, the use of both CG search and K-mean clustering will be more effective. At least, the CG search can help defining zone.
In the future, we plan on adding more subjects and more multi-pose images into the database. The face recognition system in the security system is a wide area of application to be applied especially in high security situations such as automatic teller machines, security rooms, automatic safes and confidential information access facilities.

REFERENCES
[3] R. Chellappa, C. Wilson, and S. Sirohey,