Face Recognition Based on Facial Landmark Detection

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***Abstract*— This paper presents a novel technique for face recognition based on facial landmarks extracted automatically. Our landmarks are those associated with eyes mouth and nose. With the extracted landmarks, the area triplets and the associated geometric invariance are formed. We opt to use area and triangle confined within the triangle as the invariance. To bypass the perspective constraints, we take the face image with high focal length and at the farther distance. Orthogonal projection and Euclidean transformation are then assumed. As area is relative invariance under Euclidean transformation, the absolute area ratios between consecutive area triples are applied. Our purposed algorithm is tested successfully to identify person and could be a promising technique for facial recognition.**

***Index Terms*— Facial Landmarks, Haar casecade, Face recognition.**

I. Introduction

Face recognition is technology measures and matches the unique characteristics for the purpose of personal identification to apply in many applications such as face recognition system at airport, patient identification, access control and so forth. Sometimes in traditional methods, face recognition misses matching because there are invariance factor resulted from human pose, hairstyle, acne arising, fatter etc. Hence face recognition based on facial geometric landmarks was developed and seems promising to solve these problems. Recently, there are many attempts to develop face recognition based on geometr. Panagiotis B. Perakis *et al.* [1] developed novel method for 3D landmark detection. 3D facial Landmarks Model (FLM) was proposed. Although it was claimed to have high accuracy result but the 3D technique require high specification, spending long time to process, and it has a high cost.

This paper developed 2D technique to identify person using facial geometric landmark. The technique extracts landmark associated with facial anatomical landmark including nose, eye and mouth. The geometric invariance is then constructed from area triplet formed by the landmarks. This paper is organized as follow. Section II reviews about geometric invariance. Section describes landmark extraction process. Section III explains how to extract feature. Results and conclusion is provided in section IV and V respectively.

II. Absolut Geometric Invariance

Under rigid transformation, triangle side and area is absolute invariance [2,3]. Beyond the rigid transformation, similarity and affine transformation, the triangle side lengths and angles are no longer preserved. The area of the corresponding triangles, however, becomes a relative invariant, with the two corresponding areas being related to each other through the determinant of the linear transformation matrix *T*, in the affine map transform *(T,b)* where *b* is the translation vector. If the area patches of the sequence of triangles on the template are [A(1), …, A(n)] then the corresponding area patches $A_a(k)$ of the sequence of triangles on the query under affine transformation are related to those of the template in accordance with the following relative invariant

$$A_a(k) = \begin{vmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{vmatrix} A(k), k = 1,2,3,\ldots,n \qquad (1)$$

Where $\begin{vmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{vmatrix}$ is the determinant of affine transformation matrix. As the linear transformation matrix is unknown, absolute affine invariants are constructed out of the area relative invariants by taking the ratio of two triangles to cancel out the dependence of the area relative invariant on the determinant of affine transformation matrix. By taking the ratio of the consecutive elements in the sequence, the set of absolute invariants in (2) and (3) are obtained

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$$I(k) = \frac{A(k)}{A((k+1) \bmod n)}, k = 1,2,3,\ldots,n \qquad (2)$$

and

$$I_a(k) = \frac{A_a(k)}{A_a((k+1) \bmod n)}, k = 1,2,3,\ldots,n \qquad (3)$$

In the case of noise free measurement, the absolute invariant of the query equals that of the template, i.e. $I_a(k) = I(k)$ and in the presence of noise and occlusion, each of $I_a(k)$ will have a counter part with $I(k)$, with that counterpart easily determines through a circular shift involving n comparison where n is the number of invariants. To allow for noise and small deviations from an affine map, we allow a small error percentage difference between corresponding invariants to allow for only small difference between the area patches before declare them as matching. This may reduce the length of the matched triangle sequence. The lower the error percentage is the more strict the matching. Experimentally, an error percentage of 5% was applied. We adopt a run length method to decide on the correspondence between the two ordered set of triangles. For every starting point on the sequence, the run length method computes a sequence of consecutive invariants satisfying the criterion

$$\%e^2 = \frac{(I_a(j) - I(i))^2}{I(i)^2} \times 100 < \zeta \qquad (4)$$

We declare the match on the longest string (M) of triangles that yields minimum averaged error of $\frac{\sum_i \%e_i^2}{M}$.

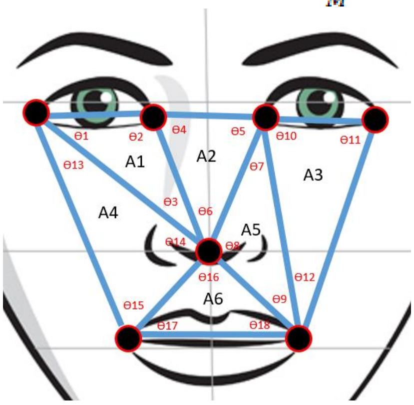
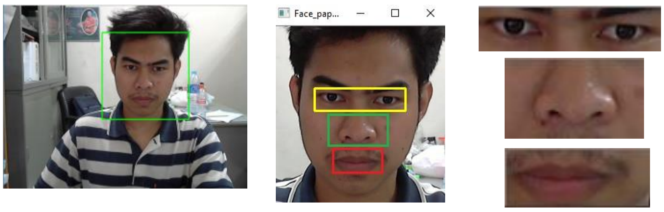


Figure 1 Areas and internal angles of facial triangles

III. LANDMARK EXTRACTION

In order to apply geometric described in section (ii), we extract facial landmarks from the 2D face image as shown in black dot of Fig 1. The landmarks are those associated with anatomical landmarks including eye, nose and mouth. With the extracted landmarks, the six area triplets are formed denoted them as A1-A6 (also shown in Fig. 1). To the facial landmarks, we first use Haar cascade algorithm to detect the face ROI as shown in figure 2 (a) following determine eye, mouth and nose ROI using the Haar cascade algorithm as shown in figure 2 (b) – (c). To find landmark associated with the eye, we convert eye ROI image to binary image using thresholding algorithm. The result is shown in Fig. 3 (b) which includes mainly the binarized region associated with eye and eyebrow.

To exclude the eyebrow region, we apply horizontal projection. The project data will then be used to separate the eyebrow region from the eye region. To detect eye-related landmark, vertical projection is applied. With the vertical projection data, the outermost pixel can be identified and the associated eye landmark can be determined (shown as yellow dot in Fig. 3 (c)).



(a) (b) (c)

Figure 2. Defined ROI of facial components by Haar cascade algorithm

(a) (b) (c)

Figure 3. Projection technique to find landmarks of eye

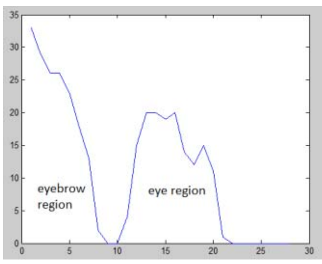


Figure 4. Projection data of Fig 3 (b)

To detect the nose-related landmark, we convert the nose ROI to binary image and apply vertical projection. The outermost pixel can be identified and the associated nose landmark can be determined (shown as yellow dot in Fig. 5 (c). Similar algorithm is applied to detect the mouse-related landmark shown in Fig. 5(c)


(a) (b) (c)

Figure 5. Projection technique to find landmarks of nose


(a) (b) (c)

Figure 6. Projection technique to find landmarks of mouth

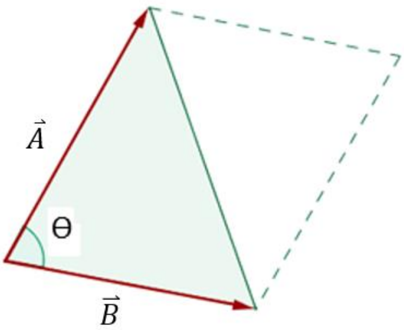


Figure 7. Vector of facial landmark

IV. Feature Extraction

With the extracted landmarks, six area triplets and 18 angles are formed as feature vectors i.e. two feature vectors are defined as

$$F_a = [A_1, \ldots, A_6] \qquad (1)$$

$$F_\alpha = [\alpha_1, \ldots, \alpha_{18}]$$

where F_a and F_α are feature vectors associated with area and angle respectively and A_x is area *xth* and α_x is angle *xth*.

To identify person, we compare F_a and F_α of the reference with the query. For F_a, we compute absolute difference of feature and estimate the average. For F_α,we compute absolute difference of feature and estimate the average of the 4 smallest error. The average error of both F_a and F_α is then used as the criterion for person identification .

The angle is computed using

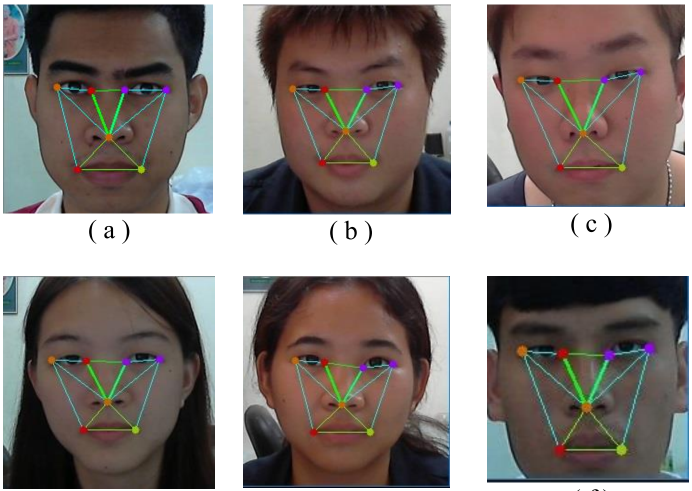
$$A \times B = |A||B|\sin(\theta)$$

$$\theta = \arcsin\left(\frac{A \times B}{|A||B|}\right) \qquad (2)$$

The area are computed via cross product

$$\text{Area of triangle} = \frac{1}{2}|A \times B| \qquad (3)$$

Where vector A and B are defined in figure 7.


(a) (b) (c)

(d) (e) (f)

Figure 8. Sample Facial Triangles result

V. Experimental and Result

We test our algorithm using the face image captured from model HD C270 Logitech webcam. The subjects sit in front of the camera with distance of 100 cm. from the camera. The camera distortion is corrected using parameter extracted from camera calibration [4]. We perform two experiments including intra-subject and inter subject experiment. The intra-subject experiment is used to verify the robustness of the purpose technique with facial image captured from different geometric transformation. The inter-subject experiment is to apply our technique in face recognition. Figure 9 shows the result of intra-subject experiment where subject performs head geometric transformation including (a) 10-degree tilt, (b) -10-degree tilt, (c) 10 –degree pan, (d) -10-degree pan, (e) 10-degree roll and (f) -10-degree roll. The average feature error is shown in Table1. To test face recognition, six subjects are tested where for each person face images are collected two times; one for reference and one for query. The query set is then tested against the reference set. The reference set is shown in Fig. 8. The result is shown in table 2. Note that the diagonal element yields the minimum average error as it is the same-person testing.

	Fig 9 (a)	Fig 9 (b)	Fig 9 (c)	Fig 9 (d)	Fig 9 (e)	Fig 9 (f)
Straight Face (Reference)	0.3868	1.3347	0.5757	1.2927	0.9015	0.9111
	0.0684	0.1029	0.0902	0.0551	0.0949	0.0822

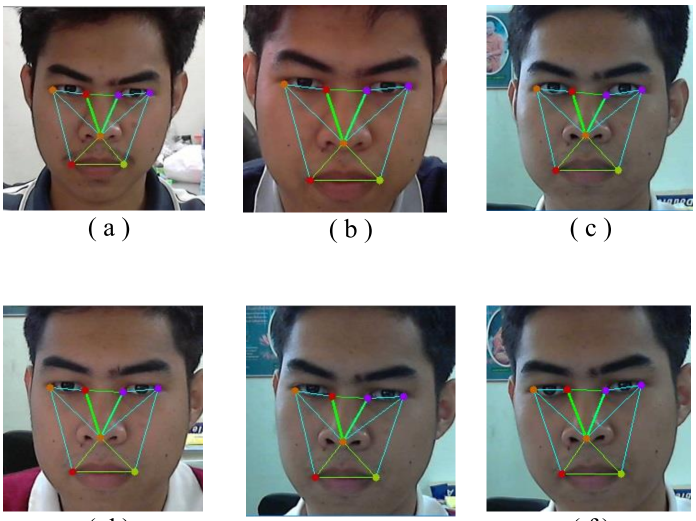
Table 1: intra-subject experiment

Upper row is average error associated with area feature vector. Lower row is average error associated with angle feature vector

	Subject 1 Face1	Subject 2 Face1	Subject 3 Face1	Subject 4 Face1	Subject 5 Face1	Subject 6 Face1
Subject 1 Face2	0.3868	1.3882	2.9298	0.4792	1.7987	3.4948
	0.0684	0.2515	0.2674	0.1543	0.2250	0.2375
Subject 2 Face2	1.0126	0.6632	0.8190	1.0009	0.9934	1.5033
	0.2487	0.0361	0.1300	0.1859	0.0598	0.4740
Subject 3 Face2	1.6895	0.6661	0.7066	0.9477	0.6825	1.0585
	0.2281	0.1871	0.0738	0.1502	0.1749	0.4369
Subject 4 Face2	1.2216	0.5829	1.6945	0.2936	0.5943	4.3963
	0.1751	0.1082	0.1117	0.0770	0.1194	0.3733
Subject 5 Face2	1.0409	0.7613	1.0728	0.8358	0.6320	2.3387
	0.3091	0.8066	0.1314	0.1379	0.0476	0.4818
Subject 6 Face2	3.3944	1.8266	1.9435	5.1168	1.9970	0.7340
	0.2638	0.4756	0.4065	0.3055	0.4927	0.0570

Table 2: inter-subject experiment

Upper row is average error associated with area feature vector. Lower row is average error associated with angle feature vector



(a) (b) (c) (d) (e) (f)

Figure 9. Facial landmark image of same person at different position

VI. CONCLUSION AND DISCUSSION

Face recognition based on geometric invariance is proposed in this paper. A facial landmark associated with anatomical landmark was extracted automatically. A series of area triplets was constructed and sorted in a formal order. A geometric invariance including area ratio and angle are then used in feature vector. A feature vector comparison is then used in facial recognition. The result of person identification using proposed techniques demonstrates promising results.

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