Improved Face Recognition Result Reranking Based on Shape Contexts

Lanchi Xie, Lei Xu, Ning Zhang, Jingjing Guo, Yuwen Yan, Zhihui Li, Zhigang Li, Xiaojing Xu
Institute of Forensic Science, Ministry of Public Security
No.17 Muxidi Nanli
100038, CHINA
+86-10-63436304
xielanchi@139.com

ABSTRACT
Automatic face recognition techniques applied on particular group or mass database introduces error cases. Error prevention is crucial for the court. Reranking of recognition results based on anthropology analysis can significant improve the accuracy of automatic methods. Previous studies focused on manual facial comparison. This paper proposed a weighted facial similarity computing method based on morphological analysis of components characteristics. Search sequence of face recognition reranked according to similarity, while the interference terms can be removed. Within this research project, standardized photographs, surveillance videos, 3D face images, identity card photographs of 241 male subjects from China were acquired. Sequencing results were modified by modeling selected individual features from the DMV altas. The improved method raises the accuracy of face recognition through anthroposophic or morphologic theory.

Keywords
Face recognition, Reranking, Shape matching, Shape contexts, Similarity calculation.

CCS Concepts
• Computing methodologies→Image processing • Computing methodologies → Shape analysis • Applied computing → Computer forensics.

1. INTRODUCTION
In the field of forensic science, human biological identification is the key evidence of criminal act. In recent years, intelligent surveillance systems were built nearly all the cities and villages. By the surveillance video systems, the target's movement is intuitively recorded, while facial identification gradually become the research hotspot. Recognizing social identity of unknown face images is a difficult issue to address, especially when the faces lack details.

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Obtaining the social identity of suspects and fugitives from surveillance videos plays a vital role in crime investigation. Facial identification technology actually includes facial recognition (FR) and facial comparison (FC), separately applied in investigation and litigation phase of a criminal case.

Facial recognition is generally considered as a branch of computer pattern recognition technique. The process are distributed into image acquisition, image pre-processing, face detection, feature extraction, feature matching. In essence, calculating a reality face by face images belonging to morbid problem, face recognition systems present result face most similar to target face from a machine's point of view. The accurate rate of the recognition is influenced by factors such as image resolution, shooting light, face expression, and so on. In spite of improvement in automatic face recognition all these years ,its application remains controversial in forensic science field.

Facial comparison originates from anthropology. Specialists discriminate individual differences with professional method from multiple views of faces. Comparing a pair of faces is a tedious task, which requires specialized trainings. The final confirmation should be made by more than two experts independently.

In practice, there are two prominent problems that limit a police face recognition system. Firstly, excessive false-alarm probability lead to a great time and money waster in targeting of suspects and escaping convicts. The classification model of automatic identification is closed to detectives, while they are not able to accurately judge the result in a short span of time. Secondly, in static face recognition system, we search a poor-quality face image from large databases and get a result list with the similarity score of each result face. It a crude way ignoring evaluation of face recognition algorithm. People without specialized knowledge can't tell the true target.

In this paper, we attempts to improve the evaluation process of face recognition system by morphological analysis method widely used in face comparison research. A more cautious decision to start legal process is the ultimate aim.

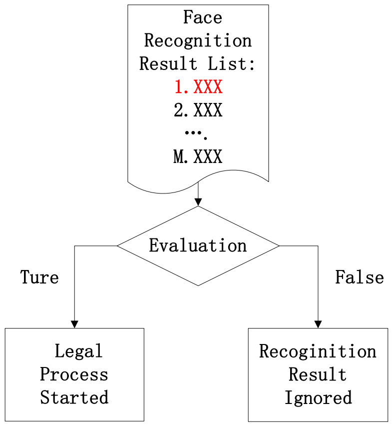

Figure 1. Result evaluation of face recognition.

The paper is divided into four sections. Section 2 introduces related research works, including face recognition algorithms, face recognition tests, and face comparison methods. Section 3 presents the proposed morphological analysis methods. Section 4 discusses the next research direction and prospects.

2. RELATED WORKS

In 1988,Kirby and Sirovich [1] displaced subjective markers calculation by principle component analysis (PCA) as the beginning sign of automate face recognition technique. With constant improvement in accuracy, FR system takes the primary responsibility in crime investigation. Figure 2 shows basic framework of face recognition system. Many researchers attempting to cut error rates by improving feature reduction algorithms [2,3,4]. However, detection rate and false alarm rate are not the only indicators in applications, the morphological specificity of human faces should be considered in facial similarity assessment.

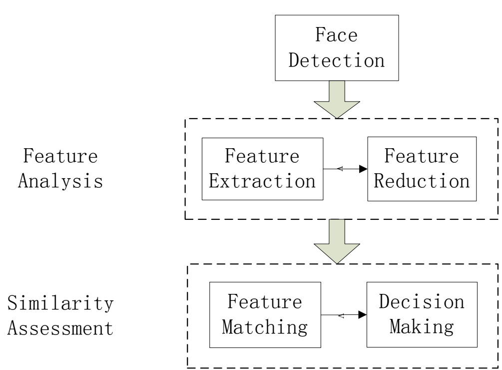

Figure 2. Basic framework of face recognition system.

2.1 Morphological Analysis

In decades, morphological analysis was the most common approach for facial comparison in legal affairs. Standards and guidelines were published by forensic organizations such as the Facial Identification Scientific Working Group (FISWG) [5]. Researchers reported numerous cases and experiments in facial consensus identification based on morphological analysis [6,7].

The facial features commonly include: the shape of mouth, eyes, nose, ears, eyebrows; the distance between each facial component; facial profile and jawline; facial mole, wrinkles and scar. Forensic specialists achieve the identical cognizance by characteristic classification. a new model of atlas called DMV [8] was developed in a project funded by the European Union. Table 1 shows frontal DMV features and characteristics.

Table 1. Frontal DMV features and characteristics[8]

Nr.	Feature	Characteristics
01	Head shape	1.Round 2.Oval 3.Rectangular 4.Pentagonal with pronounced gonion 5.Wedge shaped 6.Pentagonal with prounced cheekbones
02	Frontal height	1.Low 2.Average 3.High
03	Frontal breadth	1.Narrow 2.Average 3. Broad
04	Frontal hairline	1.Straight 2.Convex 3.Concave 4.With medial tip 5.Medially rounded ,sides back
06	Eyebrow height	1.Thin 2.Average 3.High
07	Eyebrow density	1.Sparse 2.Average 3.Bushy
08	Eyebrow shape	1.Straight 2.Laterally descending ends 3.Medial-horizontal,lateral part descending 4.Angled up 5.Narrow arc 6.Curved arc
09	Mono-brow	1.None 2.Sparse 3.Average 4. Bushy
10	Distance upper eyelid-eyebrow	1.Low 2.Average 3.High
11	Fold above upper eyelid	1.Constantly visible 2.Parly visible/hooded
12	Lid axis (neutral expression)	1.Straight 2.Laterally descending 3.Medially descending
13	Lower eyelid fold	1.Absent 2.Slightly visible 3.More cured than lower eyelid
14	Nasal root	1.Narrow 2. Average 3. Broad
15	Nose bridge length	1.Short 2.Average 3.Long
16	Nose bridge breadth	1.Narrow 2.Average 3.Broad
17	Nose bridge process	1.Regular breadth 2.Downwards broader 3.Irregular
20	Nose tip shape	1.Pointed 2.Rounded 3.Bultous
21	Nose tip incisure	1.Clefted 2.Not clefted
23	Nasal breadth	1.Narrow 2.Average 3. Long
27	Philtrum height	1.Low 2. Average 3.High
28	Philtrum depth	1.Shallow 2.Deep
29	Philtrum shape	1.Sides parallel 2.Sides divergent
30	Upper lip notch	1.Relatively straight 2.Wavy 3.Angular
31	Labial breadth (neutral expression)	1.Narrow 2.Average 3.Broad
32	Orientation of mouth corner	1.Sightly up 2.Straight 3.Sightly down

	(neutral expression)	
33	Chin shape	1.Round 2.Square 3.Pointed
34	Chin transition	1.No visible 2.Moderate transition 3. Strong transition
36	Chin dimple	1.No dimple 2.Small dimple 3.Deep dimple
41	Ear protrusion	1.Close-fitting 2.Slightly pronounced 3.Strongly pronounced
42	Transition head/neck	1.Neck dearly narrower 2.Neck slightly narrower 3.Same breadth
43	Pronunciation of cheekbones	1.Not visible 2.Slightly pronounced 3.Strongly pronounced

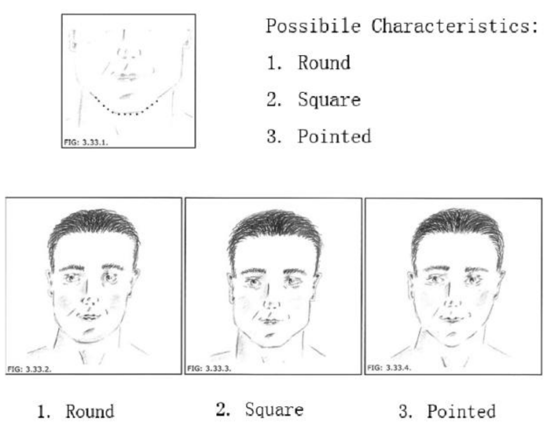

Figure 3. Possible Characteristics and Graphical Description Facial Feature Nr. 33: chin shape in the DMV atlas[9].

2.2 Shape Matching

Shape matching is the key problem in morphological analysis of facial components. Belongie proposed a new descriptor called shape contexts(SC) [10], which was proved to be effective in recognition of non-rigid objects.

In the approach of shape contexts, the objects are considered as infinite points. Shape of the objects can be described by a set of finite points. Edge detector generates the inner or external contours, and then sampler selects parts of the contour points uniformly according to the pixel spatial positions. The set of sampling points P includes n points:

$$P = \{ p_1, \cdots, p_n \}, p_i \in R^2 \quad (1)$$

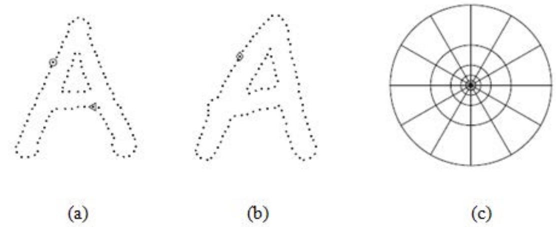

Figure 4. Shape contexts computing.(a, b) sampled edge points of two shapes. (c) diagram of log-polar histogram bins used in computing the shape contexts[10].

To describe the position distribution of a shape, coarse histogram was introduced h_i by computing relative vector between a certain point p_i and the n-1 other points. Surrounding p_i, the space is divided into log-polar histogram bins, showed in Figure 4. (c).

$$h_i(k) = \#\{q \neq p_i; (q - p_i) \in bin(k)\} \quad (2)$$

Based on it, Ling [11] proposed a inner-distance shape context method, which introduced inner distance instead of Euclidean distance and got better performance on internal deformation of objects. Zhou [12] raised angle context model to compute facial similarity. This model was more streamlined., but the selection of the target shape points on the face appeared to be at random.

3. PROPOSED METHOD

Shape matching method based on shape contexts constructs a histogram ,while computational complexity limiting factor for automatic face detecting and matching. However, we regard it as a proper method for reranking of face recognition result.

In practice, we firstly collected a image database including 2D face images,3D images and surveillance video of volunteers. Based on the database, we analysed morphological features of certain face in different data form. Then stable shape features under surveillance videos were selected from the 43 DMV altas. Point distribution model was introduced to find shape points of the target feature. Thus, a few critical points remained, we can calculate the similarity of feature shapes from two faces. Lastly, re-rank the recognition result.

3.1 Data Acquisition and Face Recognition

In this study, 286 adults were selected as subjects, including 241 males and 45 females. Taking age distribution of crime groups into account, the age of selected test subjects was in a range of 17 to 64. Acquisition time is October 28-30, 2014. All portrait data collected in the room under natural light.

Four types of data was collected from a single person: frontal face photograph, 3D scanning face image, surveillance videos, and standard ID photo (taken 3months to 9 years before the acquisition time).

Table 2. Specific information of data acquisition

Data type	Acquisition equipment	Acquisition time	Image size (pixels)
2D image	Canon EOS-1DX	Oct. 2014	5184 ×3456
3D image	Artec Spider hand-held 3D scanner	Oct. 2014	4096 ×4096 (texture image)
CCTV	HIK / DS-7804H hard disk video recorder	Oct. 2014	352 ×288
ID photo	-	2005-2014	358 ×411

To simulate realistic scenes of crime investigation, we selected target screenshots in different shades, expressions and frontal poses. Then these screenshots entered a common face recognition system with a search scope of 100 thousands faces. Statistics suggested the recognition accuracy rates were 41% (Top 1), 53% (Top 5) and 57% (Top 50). The error rates are significantly higher than research data, in accord with the experience of investigators. Re-ranking of FR result list is considered to be the optimal approach.

Figure 5. Target screenshots of surveillance videos.

3.2 Similarity by Morphological Analysis

3.2.1 Target facial feature

Ritz-Timme reported a set of manual recognition experiments on the 43 DMV altas of human face [13]. Professional and non-professional observers were invited to identify characteristics of faces features. The highest mismatch percentage occurred in identification of the eyebrow shape (feature Nr. 8), the nose (feature Nr.22), the alar wing length (feature Nr. 24) and the ear breadth (feature Nr. 38).

The most important direction of reranking is reducing human error in identification from the list of FR result. We should put great attention on features prone-to-error. Since feature Nr.22, feature Nr.24 and feature Nr.38 are lateral facial features, they are sometimes invisible in surveillance videos.

We analyzed the surveillance videos in our database, and 3 to 4 approximately frontal screenshot images from each object were selected. Firstly, record the visibility of the 31 frontal DMV altas in surveillance videos. Secondly, professional observers and FR systems were introduced to recognize the characteristics of 31 altas. Thirdly, performance of the experts and machines was evaluated. Influencing factors were listed by the end. The result of these works were showed in Table 3.

Table 3. FC and FR tests of 31 frontal DMV altas

Nr.	Visibility	Performance in FC	Performance in FR	Influencing factor
01	fair	fair	poor	pose
02	poor	good	poor	verlap
03	poor	fair	poor	pose
04	poor	poor	good	pose
06	good	good	poor	pose
07	good	good	poor	-
08	good	poor	good	-
09	rare	-	-	-
10	good	fair	fair	pose
11	fair	good	fair	illumination
12	good	good	poor	expression
13	poor	good	fair	resolution
14	good	fair	poor	illumination
15	good	fair	fair	-
16	good	fair	poor	-
17	fair	good	fair	pose
20	good	good	poor	-
21	fair	good	fair	expression
23	poor	fair	fair	pose
27	good	good	fair	-
28	fair	good	poor	-
29	poor	fair	good	resolution
30	poor	good	fair	resolution
31	good	good	fair	expression
32	good	good	poor	expression
33	fair	fair	poor	resolution
34	poor	fair	poor	illumination
36	poor	good	fair	resolution
41	fair	good	good	verlap
42	good	good	fair	pose
43	fair	good	poor	pose

According to the above researches ,we chose the eyebrow shape (feature Nr.8) to be the target feature.

3.2.2 Facial feature points location

The next step is pre-processing of facial image. In this paper, we use ASM（Active Shape Model）Library tool to detect 68 feature points on the object faces. ASM algorithm possesses training part and searching part [14]. Frequently-used training datasets includes IMM database, Franck database, Helen database, and etc. We assume that training dataset contains n marked faces and each face has k feature marks. A shape vector can be expressed as:

$$a_i = (x_1^i, y_1^i, x_2^i, y_2^i, \ldots, x_k^i, y_k^i) \qquad i = 1,2,\ldots,n \quad (3)$$

Shape vectors relatively aligned, PCA processing takes place. Then we build description of local feature by iteration. To each feature point, local texture g_{ij} is the gray level derivative of 2m+1 vectors. The mean $\bar{g}_i$ and variance S_i are considered as the local texture of feature point i. The similarity f_{sim} between a new feature point and training data can be calculated as:

$$f_{sim} = (g - \overline{g_i}) \cdot S_i^{-1} \cdot (g - \overline{g_i})^T \qquad (4)$$

On the basis of training, the tool search corresponding shape on object's face. Figure 6 shows the location of facial feature points computed by ASM tool. 12 feature points of the eyebrow shape (feature Nr. 8) are noted.

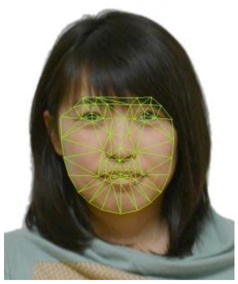

Figure 6. Location of facial feature points computed by ASM.

3.2.3 Similarity based on shape context

Using ASM tools, we get 12 feature points of the eyebrow shape. In video detection application, poses still vary in approximately frontal faces. We measured the distances between inner corners and outer corners of the eyes, and chose the left or right eyebrow shape to be computed. Then more-refined pre-processing, edge extracting and uniform sampling were operated on the local image.

Take the right eyebrow shape for example, the origin is located on the right eye pupil centre. Under polar coordinate system, we divided 3 bins for r and 12 bins for θ. Since 6 feature points of the right eyes already known, these bins were properly built covering all the contour points of the shape ,as shown in Figure 7.

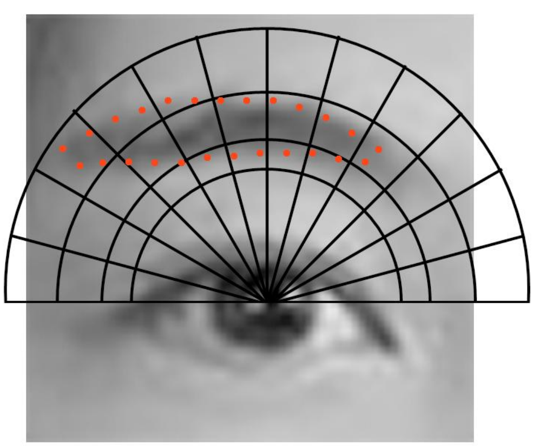

Figure 7. Division of SC bins on the shape of right eyebrow.

For a shape point p_i on a given face, we computed the SC histogram $h_i(k)$:

$$h_i(k) = \#\{q \neq p_i ; (q - p_i) \in bin(k)\} \qquad (5)$$

where k=1,2,...,36.

We constructed a matrix to model the target eyebrow shape:

$$w = \begin{bmatrix} h_1(1) & \cdots & h_1(36) \\ \vdots & \ddots & \vdots \\ h_n(1) & \cdots & h_n(36) \end{bmatrix} \qquad (6)$$

The similarity of the target shape S and a unknown shape S' is:

$$f_{sim}(S, S') = \frac{\sum_{i.k} \min\left(h_i(k) - h'_i(k)\right)}{n \cdot 36} \qquad (7)$$

Base on the similarity computation, we reranked the result list of FR system, as shown in Figure 8. Morphological analysis is an area of expertise, Simplified shape modeling and matching tend to the significant improvement for reducing artificial error in application of FR result.

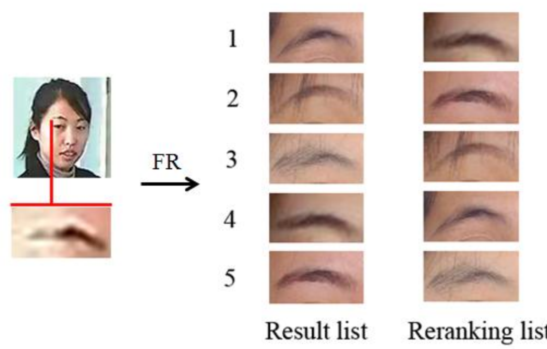

Figure 8. Reranking of face recognition result based on the similarity computation of the eyebrow shapes

4. Conclusions

In this paper, we proposed a novel face recognition result reranking method. Firstly a multi-type database was built to analyze facial features. Secondly we used the ASM tool to locate feature points of the objects. Then the eyebrow shape (feature Nr.8) was chose to be the target feature. Similarity was computed based on shape contexts. Lastly, reranking was taken according the similarity of target feature. Large-scale blind tests are of great necessity in evaluation of the reranking results. At the present stage, we choose the only facial shape (shape of eyebrow) to simplified the method. More further research should be carried out in multi-shape similarity computation based on the rich facial identification experience.

After all these years researching, FR turns to be a mature technique. However, plenty of limiting factors put the forensic application of FR at a quite awkward position.This paper brought a new idea that morphological analysis of anthropology can be introduced in reranking of the result list. For users of FR system, it's a novel attempt that struggled to fill the knowledge gap between experts and regular people by means of automatic matching computation.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] L. Sirovich and M. Kirby. 1987. *A Low-Dimensional Procedure for the Characterization of Human Faces*. Journal of the Optical Society of America A Optics & Image Science, 1987, 4(3):519-24.

[2] Penev, P. S. 2004. *Independent manifold analysis for subpixel tracking of local features and face recognition in video sequences*. Proceedings of SPIE - The International Society for Optical Engineering, 5404, 523-533.

[3] Park, S. W., & Savvides, M. 2007. *Individual kernel tensor-subspaces for robust face recognition: a computationally efficient tensor framework without requiring mode factorization*. IEEE Transactions on Systems Man & Cybernetics Part B Cybernetics A Publication of the IEEE Systems Man & Cybernetics Society, 37(5), 1156-66.

[4] Sundaresan, A., & Chellappa, R. 2008. *Model driven segmentation of articulating humans in laplacian eigenspace*. IEEE Transactions on Pattern Analysis & Machine Intelligence, 30(10), 1771-1785.

[5] Facial Identification Scientific Working Group (FISWG). 2010. *Facial Comparison Overview* .Version of 29.04.2010, DOI= http://www.fiswg.org/FISWG_Facial_Comparison_ Overview_v1.0_201 0.04.29.pdf>

[6] Ritztimme, S., Gabriel, P., Tutkuviene, J., Poppa, P., Obertová, Z., & Gibelli, D., et al. 2011. *Metric and morphological assessment of facial features: a study on three european populations.* Forensic Science International, 207(1-3), 239.e1-8.

[7] Ventura, F., Zacheo, A., Ventura, A., & Pala, A. 2004. *Computerised anthropomorphometric analysis of images: case report*. Forensic Science International, 146 Suppl(146 Suppl), S211-S213.

[8] Park, S. W., & Savvides, M. 2007. *Individual kernel tensor-subspaces for robust face recognition: a computationally efficient tensor framework without requiring mode factorization*. IEEE Transactions on Systems Man & Cybernetics Part B Cybernetics A Publication of the IEEE Systems Man & Cybernetics Society, 37(5), 1156-66.

[9] Ritz-Timme, S., Gabriel, P., Obertovà, Z., Boguslawski, M., Mayer, F., & Drabik, A., et al. 2011. *A new atlas for the evaluation of facial features: advantages, limits, and applicability*. International Journal of Legal Medicine, 125(2), 301-6.

[10] Belongie, S., Malik, J., & Puzicha, J. 2010. *Shape matching and object recognition using shape contexts*. IEEE Transactions on Pattern Analysis & Machine Intelligence, 24(4), 509-522.

[11] Ling, H., & Jacobs, D. W. 2007. *Shape classification using the inner-distance*. IEEE Transactions on Pattern Analysis & Machine Intelligence,29(2), 286-99.

[12] S.Y. Zhou. 2007. *Research and application on the algorithm of shape similarity*(in Chinese) . Academic Dissertation, Zhejiang University.

[13] Cootes, T. F., Taylor, C. J., Cooper, D. H., & Graham, J. 1995. *Active shape models-their training and application.* . Computer Vision & Image Understanding, 61(1), 38-59.