Preliminary Identification of Fingerprint based on Shape Features

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ABSTRACT
The objective of this paper is to extract some distinct shape features of an image with combination of morphological operation and Gabor filtering. The main application of shape feature is to recognize a geometric shape, for example detection of fonts of a language but here we consider fingerprint as test case. Although core and minutia points (bifurcation and termination of ribs) are the distinct feature of a fingerprint but we emphasis on the shape feature of the image as the preliminary identification. The technique used here can be combined with minutia based identification technique to enhance confidence level. Among fifty widely used shape features, only nine spatial and central moments of different order are considered here. We consider two connected components of a binary fingerprint, which provides the maximum number of non-zero elements. Like conventional geometric shape, our analysis reveals similarity or dissimilarity of a test fingerprint with the stored samples of database.

Keywords
Spatial and central moments, Bangla fonts, Mathcad, Gabor filter and Morphological operation.

1. INTRODUCTION
Shape is a powerful cue for object recognition because of its unique property of invariance in translation, rotation and scaling operations. Shape feature is important because it acts as an alternative to object taking into account only the important characteristics of it and thus reduces the amount of information stored. Efficient shape features possess some essential properties such as identifiability, translation, rotation and scale invariance, affine invariance, noise resistance, occultation invariance, statistical independence and reliability. The process of extracting feature that is able to represent and express things better from the original object or image is referred to as feature extraction. Broadly speaking, it is a process of transformation of image matrix shown in detail in [1]. Shape feature has wide application in biometrics, automation, pattern recognition, geometric modeling and image processing. Feature extraction and segmentation play key role in medical image processing and computer-aided diagnosis. RiboGe and HailongShen performed in-depth analysis on brain CT Image extracting its shape features discussed in [2]. Shape features are also used extensively in Content based image retrieval(CBIR) where the image is retrieved from image databases through shape, color or texture rather using any keyword or tag. ReshmaChaudhari, and A. M. Patil presented a content based image retrieval methodology based on color and shape features discussed in [3]. Shape feature extraction is employed in novel image retrieval method that uses gradient operator and slope magnitude technique with Block Truncation Coding. Four variations in the method are presented using gradient masks like Robert, Sobel, Prewitt and Canny found in [4]. Shape features extraction is a crucial step in Modified Shape Description (MSD) feature extraction technique explained in [5]. This technique generates shape feature vector for each image using edge detection technique with threshold method and finally the discriminating feature vector is developed for each image employing shape, texture and color. Contour based and region based methods are two shape representation methods. Contour based methods only consider shape boundary information while region based methods take into account all the pixels within the region [6]. Robert Osada, Thomas Funkhouser, Bernard Chazelle and David Dobkin proposed a method for computing shape signature of an object as a shape distribution measuring its global geometric properties. The key advantage of this method is that the shape matching problem is reduced to the matching of two probability distributions unlike other shape matching methods that considers the pose registration, parameterization, feature correspondence, model fitting etc. [7].

The paper is organized like: section 2 provides the detail mathematical analysis of shape features of an image, Gabor filtering technique with the impact of Gabor parameters on the shape of characteristics curve and the algorithm in extracting the features of an image, section 3 provides the results based on analysis of section 2 and section 4 concludes the entire analysis.

2. SYSTEM MODEL
2.1 Shape features
An image is characterized by different shape features like centroids, spatial variances (along x axis, y axis, principle component axis, perpendicular to principle component axis), ratio of the area of the component to the area of the entire image, standard spatial moments and central spatial moment [8]. The fundamental morphological operations like erosion and dilation can be applied on an image prior extracting the shape features.
The centroid of an image of $N\times M$ is expressed as [9]:

$$\left(C_x, C_y\right)=\left(\frac{1}{N}\sum_{i=0}^{N-1}x_i, \frac{1}{N}\sum_{i=0}^{M-1}y_i\right) \quad (1)$$

;where (x_i, y_i) is the co-ordinate of ith pixel.
The (r, s)th spatial moment of an image represented by function $f(x,y)$ is expressed as:

$$M_P\left(r, s\right)=\sum_{j=1}^{N}\sum_{k=1}^{M}x_j^r y_k^s f\left(j, k\right) \quad (2)$$

; where $x_j = j+1/2$ and $y_k = k+1/2$
The normalized version of spatial moment,

$$M_{P\_n}(r,s)=\frac{1}{N^r M^s}\sum_{j=1}^{N}\sum_{k=1}^{M} x_j^r y_k^s f(j,k) \qquad (3)$$

; where its value lies in the range: $-1 \le M_n(r,s) \le 1$

The spatial central moment of the same image in normalized form is expressed as:

$$M_{C\_n}(r,s)=\frac{1}{N^r M^s}\sum_{j=1}^{N}\sum_{k=1}^{M}\left(x_j-\bar{x}\right)^r\left(y_k-\bar{y}\right)^s f(j,k)$$

(4)

;where

$$\bar{x}=\frac{M_{1,0}}{M_{0,0}} \quad M_{1,0}=M_{P\_n}(1,0)=\frac{1}{N}\sum_{j=1}^{N}\sum_{k=1}^{M} x_j f(j,k) \text{ and}$$

$$M_{0,0}=M_{P\_n}(0,0)=\sum_{j=1}^{N}\sum_{k=1}^{M} f(j,k)$$

The unscaled central moment,

$$M_{C\_n}(r,s)=\frac{1}{N^r M^s}\sum_{j=1}^{N}\sum_{k=1}^{M}\left(x_j-\bar{x}\right)^r\left(y_k-\bar{y}\right)^s f(j,k) \qquad (5)$$

;where $\tilde{x}=\frac{M'_{1,0}}{M'_{0,0}}$

$$M'_{1,0}=M_P(1,0)=\sum_{j=1}^{N}\sum_{k=1}^{M} x_j f(j,k) \quad \text{and}$$

$$M'_{0,0}=M_P(0,0)=\sum_{j=1}^{N}\sum_{k=1}^{M} f(j,k)$$

In this paper we consider the following moments serially as the index from 18 to 26 according shape feature function of Mathcad 14:

Standard spatial moment: (0,2), (2,0), (1,2), (2,1), (0,3), (3,0)

Central spatial moment: (0,0), (0,1), (1,0).

2.2 Gabor filter

Gabor filters are widely used in image processing, computer vision and pattern recognition since it can provide accurate time-frequency location of an image matrix. Recent literature shows that Gabor filter is a powerful way to extract features of biometric images: fingerprint, iris, human face etc. The analysis is found with mathematical explanations in [10-11]. The two dimensional impulse response of a Gabor filter is expressed as,

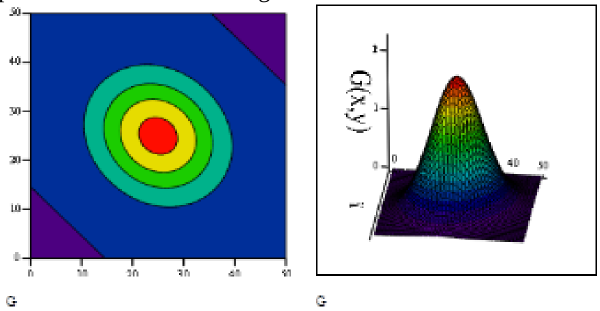
$$G(x,y)=\frac{e^{-\frac{G_1(x,s,\theta,N)}{2\sigma^2}G_2(x,s,\theta,N,\lambda)}}{\sqrt{2\pi}\sigma} \qquad (6)$$

;where

$$G_1(x,s,\theta,N)=\left\{\frac{x-s}{N}\cos(\theta)+\frac{y-s}{N}\sin(\theta)\right\}^2+\gamma^2\left\{\frac{-x+s}{N}\sin(\theta)+\frac{y-s}{N}\cos(\theta)\right\}^2$$

$$G_2(x,s,\theta,N,\lambda)=\cos\left\{2\pi\frac{\frac{x-s}{N}\cos(\theta)+\frac{y-s}{N}\sin(\theta)}{\lambda}+\Psi\right\}$$

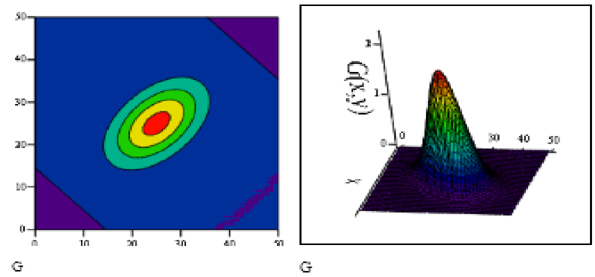
;Where *s* is the center of the filter i.e. the footprint of the peak point, γ is the BW of the Gabor filter. The smaller the value of γ the wider is the BW, θ is the orientation of the filter characteristics curve on *x-y* plane, σ (is the standard deviation of the Gaussian envelope) determines the shape of the surface i.e. circular or elliptical footprint also called Gaussian with of the filter, ψ is the phase shifts the footprint along y axis, λ governs width of the footprint along *y* axis. The significance of parameters of characteristics equation of Gabor filter is found in [12-13]. The surface and contour plot of characteristics curve of a Gabor filter with typical values of parameters are shown in Fig.1.



(a) Contour plot (b) Surface plot

Fig 1: Characteristics curve taking $N = 50$, $\theta = \pi/4$, $\lambda = 2$, $\sigma = 0.18$ and $\gamma = 1$

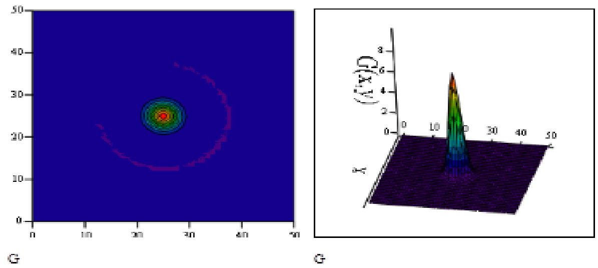
Changing the value of γ to 2 provides the following change (orientation and shape of elliptical surface of filter on *x-y* axis w.r.t. *z* axis) in characteristics curve shown in Fig.2.



(a) Contour plot (b) Surface plot

Fig 2: The impact of γ on characteristics curve

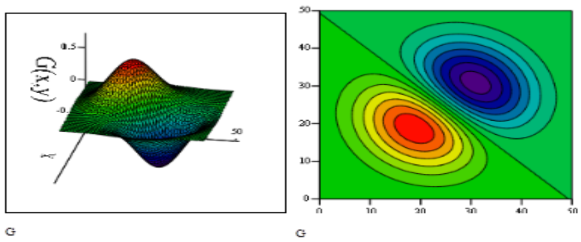
Reducing the standard deviation σ from 0.18 to 0.02 reduces the BW of the filter visualized from Fig.3.



(a) Contour plot (b) Surface plot

Fig 3: The impact of σ on characteristics curve

Finally the impact of ψ i.e. changing its value from 0 to 1.6 is shown in Fig.4 which actually changes the polarity of amplitude characteristics.



(a) Contour plot (b) Surface plot

Fig 4: The impact of ψ on characteristics

The filtering of an image in $\mathbf{I}(x,y)$ domain is expressed as,

$$\mathbf{f}(x,y) = \mathbf{I}(x,y) * \mathbf{G}(x,y) \quad (7)$$

Taking Fourier transform we get the relation in (u,v) domain as,

$$\mathbf{F}(u,v) = \mathbf{R}(u,v)\mathbf{S}(u,v); \quad (8)$$

;where $\mathbf{F}(u,v) \leftrightarrow \mathbf{f}(x,y)$, $\mathbf{R}(u,v) \leftrightarrow \mathbf{I}(x,y)$ and $\mathbf{S}(u,v) \leftrightarrow \mathbf{G}(x,y)$

2.3 Algorithm

After binarizing a fingerprint image we get several connected components but in this paper we consider the shape features only for two connected components which provide the maximum number of non-zero elements. The entire operation of the paper can be summarized with the following algorithm.

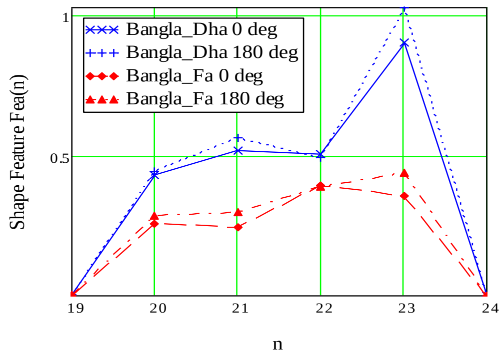
1. Read an image.
2. Convert it into binary image.
3. Apply morphological operation on the image.
4. Determine the shape features of the image using Mathcad function *shape_features*($\mathbf{I}_{AP}$); where $\mathbf{I}_{AP}$ is the image after preprocessing.
5. Above function in Mathcad determines shape features for all possible connected images but we select only two connected images provide the maximum possible non-zero values.
6. Compare shape features with the shape features of existing images in database.
7. Repeat the steps 1-6 including 'filtering of image' with low pass (LP) Gabor filter as the preprocessing on the image.

The results based on above algorithm are shown in next section.

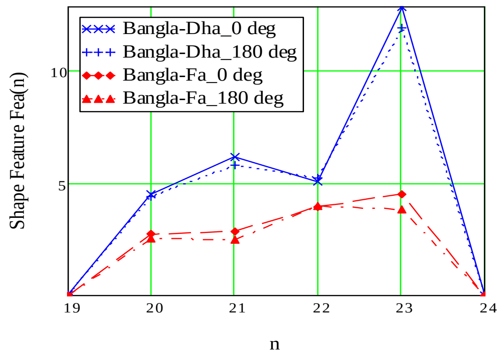
3. RESULTS

Let us now concentrate on Bangla font (font of language of Bangladesh and West Bengal of India) where we consider only Fa and Dha. The original font, its rotation of 180 degree and Gabor filtered version is shown in Fig.5. Fig.6 shows the variation of spatial moment of Fa and Dha where rotation of image could not change the amplitude or slope of moment profile but in case of different Bangla font both amplitude and slope of profile changes widely hence the technique is applicable in font detection. Finally the impact of erosion and dilation is shown in Fig.7 where there is no significant improvement hence it is visualized that erosion and dilation does not work satisfactory on low frequency components of an image. But if we reduce the BW of the filter i.e. variance σ^2 is reduced from 0.2 to 0.02 then we get the best result of the thesis shown in Fig.8 specially the second row of the feature matrix uses no additional space above the subsection head.

Fig 5: Bangla fonts, its rotation and filtered version

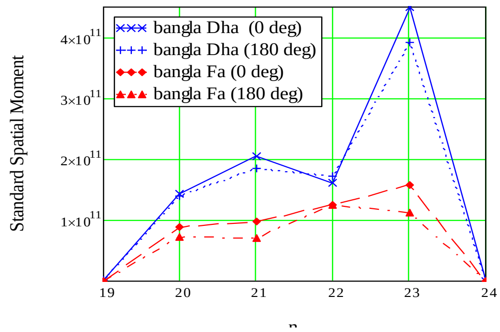


(a) 1st row

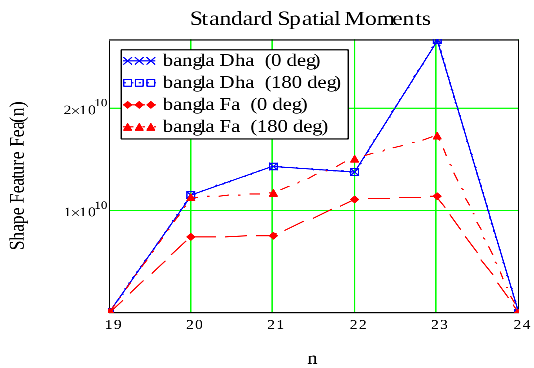


(b)2nd row

Fig 6: Variation of standard spatial moment of bangle Fa and Dha using Gabor filter

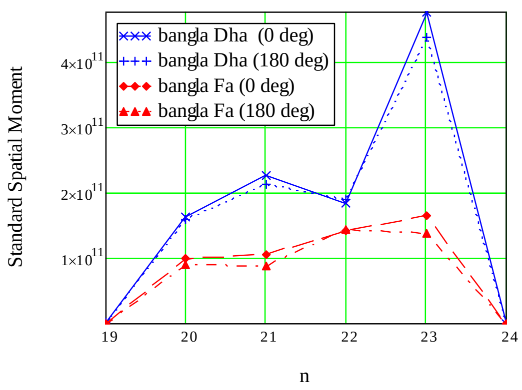


(a)1st row

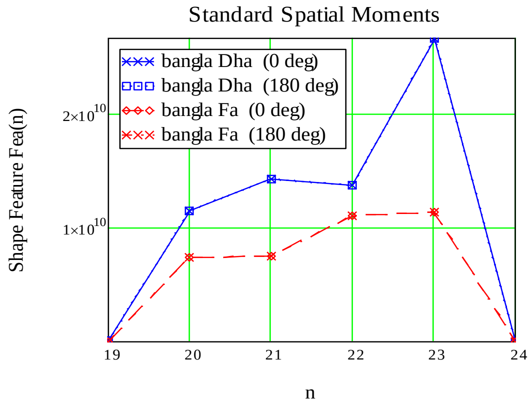


(b) 2nd row

Fig 7: Variation of standard spatial moment of Bangla Fa and Dha using Gabor filter ($\sigma^2 = 0.2$) incorporation dilation and erosion



(a)1st row



(b)2nd row

Fig 8: Variation of standard spatial moment of Bangla Fa and Dha using Gabor filter ($\sigma^2 = 0.02$) incorporation dilation and erosion

Here we consider two test fingerprints: first one is with single core and the second one with double core. The original gray scale fingerprint, corresponding binary image, dilated image and image after erosion of first fingerprint is shown in Fig.9 (a)-(d). The corresponding images of second fingerprint are shown in fig. 10(a)-(d).


(a)Original gray scale (b) Binary image


(c) Dilated image (d) Image after erosion

Fig 9: Four different form of first fingerprint

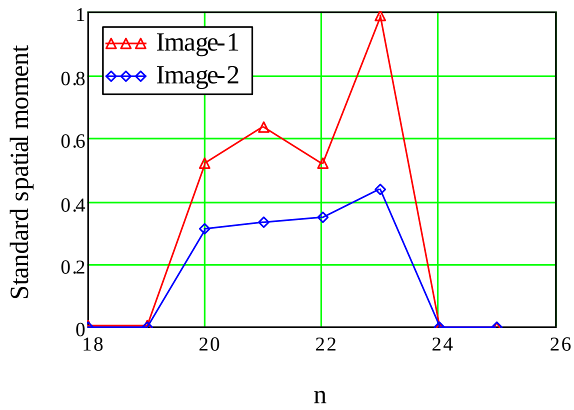

(a) Original Gray scale (b) Binary image


(c) Dilated image (d) Image after Erosion

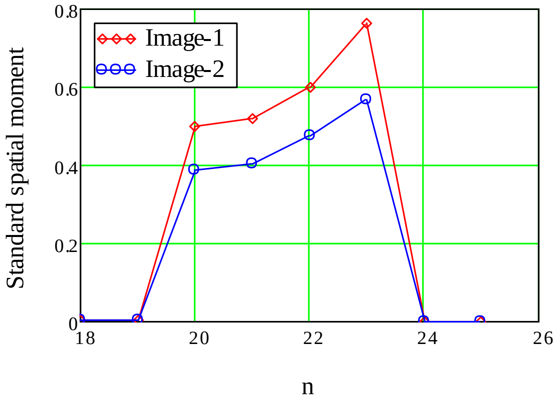
Fig 10: Four different form of second fingerprint

Let us first compare the standard spatial moment of two images after dilation only (18^{th} to 26^{th} components of features). Fig. 11(a) and (b) show the profile of features of 1^{st} and 2^{nd} row and reveal wide variation on 20^{th} to 23^{rd} elements. The corresponding results under combination of erosion and dilation are shown in Fig. 11(a) and (b). Here we used normalized value to observe the relative difference between two images. Finally we compare the invariant moment of two images under above two cases in Fig.11. The invariant moments show wide variation after combination of dilation and erosion. The entire analysis shows that each of the pair of profile shows variation in amplitude but variation in slope of curves is small.

To overcome above situation let us filter the images using Gabor filter. The characteristics curves of Gabor filter and the corresponding filtered images are shown in Fig.13. Now the standard spatial moment shows wide variation visualized from Fig.14. Low frequency components dominate on spatial moment is verified from above technique.

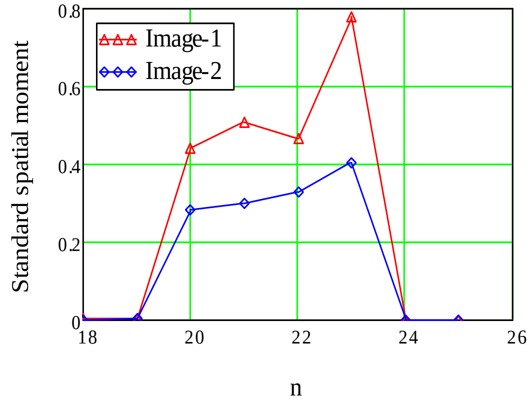


(a)1st connected component

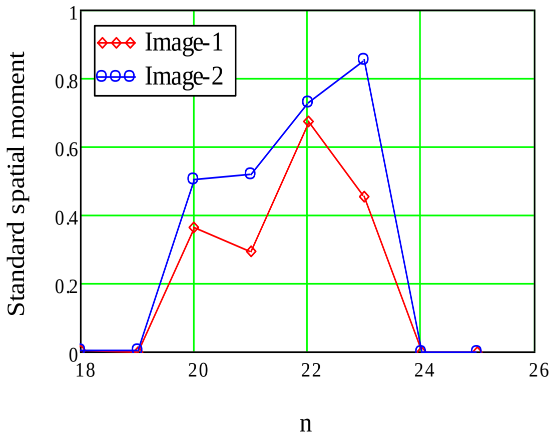


(b)2nd connected component

Fig 11: Variation of standard spatial moment only using dilation

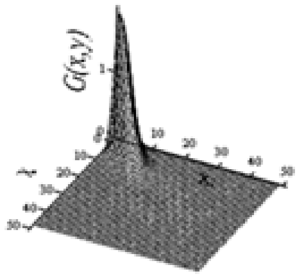


(a) Only dilation



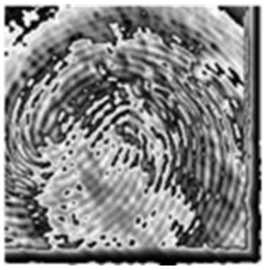
(b) Combination of Erosion and Dilation

Fig 12: Variation of invariant moment



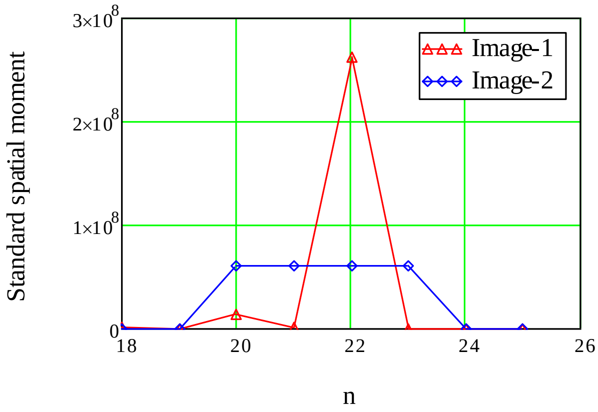
(a) Characteristics of Gabor filter

(b) Filtered image-1

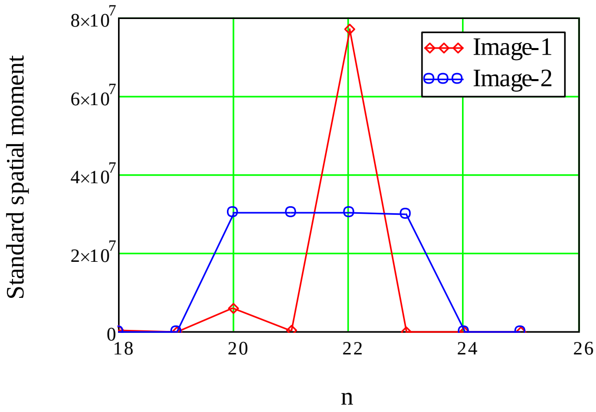


(c) Filtered image-2

Fig: 13. Filter image with characteristics curve of Gabor filter



(a)1st connected component



(b) 2nd connected component

Fig 14: Variation of standard spatial moment using erosion and dilation with LP Gabor filter

4. CONCLUSION

In this paper we measure the similarity and dissimilarity of fingerprints using spatial and central moment of image of different orders. First of all we worked on Bangla font and we are able to identify all the letters successfully irrespective of rotation. The situation is not so favorable in case of fingerprint since the technique can distinguish fingerprint of single, double core or the fingerprint of no core cases. We worked on 115 fingerprint and found the success of 78 for the case of direct extraction of shape feature, 85 with application of morphological operation and 90 with application of low pass Gabor filtering. The success rate of the technique is much less than the case of minutia point based analysis hence the analysis of fingerprint with shape feature can be a supporting method of 'minutia based extraction technique' to enhance success rate of above method. We can also apply the technique in preliminary identification of human face or can be combined with PCA (principal component analysis) technique to increase the success rate.

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