# Multiple Features from Palm Region to Enhance the Performance of Biometric Verification System

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***Abstract*— This paper presents a multimodal biometric verification system based on palm print, heart line shape and geometric feature of human hand. The hand image captured using digital camera is preprocessed to find the palm print ROI (region of interest) that has heart line. Palm print texture features are extracted by applying local binary pattern method and Gabor filters are applied on palm ROI to extract heart line feature. Geometry features are represented as distances between different boundary points located on palm region of hand. A simple yet robust decision level AND rule is proposed for developing an efficient biometric based person verification system. The proposed system is tested on database collected at our institute. The equal error rate (ERR) of the proposed system is 2.53%. Experimental results clearly indicate that combining heart line shape and hand geometry feature with palm print features at decision level improves the performance of the verification system.**

***Index Terms*— biometrics, palm print, principal lines, verification**

## I. Introduction

THE capability of verifying the identity of individuals called as person recognition is essential to several civilian and commercial applications to provide access to secured resources. Traditional recognition approaches which are based on what a person knows or what a person has are not sufficiently reliable to satisfy the security requirements due to the use of several advanced techniques of forgery and identity impersonation methods. Therefore, new approaches for verifying the identity of individuals are greatly needed. In recent years biometrics based recognition systems are being used as an alternative to traditional recognition approaches. Biometric recognition is based on physiological traits such as finger print, palm print, iris, face and behavioral traits such as gait, signature and voice. Biometric system that uses only one biometric trait are referred to as unimodal systems and those that use more than one are multimodal systems. Unimodal biometric systems are affected by problems like noise in captured biometric image, lack of distinctiveness of the biometric trait and spoof attacks. Due to these problems error rates associated with unimodal systems are quite high and consequently it makes them unacceptable for deployment in civilian and commercial applications. To overcome the disadvantages of unimodal systems multimodal biometric systems are being extensively developed to decrease the possibility of circumventing the system and to enhance the performance by using more features. Among the various traits deployed hand related traits such as palm print, hand geometry and finger knuckle prints have gathered more attention over past few years because of their performance and inexpensive acquisition devices to capture biometric data. Since several types of biometric features can be extracted from hand image we focus on using palm region features in our work for developing a verification system.

Biometric system consists of two subsystems, one for enrollment and second one for recognition. In the enrollment stage biometric data are acquired from the individuals. Features are extracted from the acquired data and multiple feature vectors (templates) per individual are computed (probe template) and are stored in the database. In the recognition stage, biometric data (test data) of an individual is captured and multiple templates (query templates) are computed. Query templates are compared with the templates retrieved from the database created during enrollment. Biometric systems can operate in two modes, Verification and Identification. Verification refers to confirming or denying a person’s claimed identity. In this mode the system performs one to one comparisons of the query template with the probe templates of claimed identity stored in the database during enrollment. Identification refers to establishing a person’s identity. In this mode, query template is compared with the templates of all persons enrolled into the database to establish an individual's identity. The focus of this work is to observe the improvement in the performance when more features are integrated and to analyze the suitability of the selected features in developing a biometric based recognition system to operate in verification mode [1]-[4].

Rest of the paper is organized as follows. Section 2 provides a brief review of research with respect to hand related traits. The description of the proposed approach is described in section 3. Following it, section 4 presents experimental results and analysis of the results obtained. Finally conclusions of this work are given in section 5.

## II. Related Work

Several research work on hand related traits have been reported in biometric literature. Palm is the inner region

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between wrist and base of fingers having features such as principal lines, wrinkles, datum points, delta points and minutiae. Wrinkles are thin irregular lines forming the texture of palm print. Most of the hand traits based recognition methods employ mainly geometrical features of hand, texture and line features from palm region. If geometrical or principal line features alone are adopted as discriminating biometric feature then there is possibility of more than one person having similar features. Whereas the print patterns on palm region are considered as one of the important characteristic because of its uniqueness and stability. Palm print pattern are found to be distinct even in monozygotic twins [5].

Feature extraction algorithms employed in palm print recognition can be classified as line based, subspace based, statistical-based and coding based methods.

Line detection based methods commonly extract lines using edge detectors which are matched directly or represented in other formats for matching two palm print images. Finite radon transform, canny edge detector, modified finite radon transform, cartelistic of roof edges, consecutive filtering operations related to gradient, morphological operators and steerable filters are used by researchers in [6]-[11] to extract principal lines. Recognition based solely on principal lines fails to perform well when more persons are enrolled into the recognition systems due to the possibility of different persons having similar principal lines.

Principal component analysis (PCA) and linear discriminant analysis (LDA) are the two well known subspace learning methods used in biometric literature to find a low dimensional sub space in a high dimensional input space by liner transformation. Computed coefficients in the sub space are regarded as features which are used for recognition. Lu et al. proposed an approach to extract features by using PCA in [12]. Karhunen-loeve transformation approach is used by authors to project the palm print image into a relatively low dimensional feature space called eigenpalms. A similar technique was employed by Wu et al. in [13] using Fisher linear discriminant (FLD) to project the palm print images into reduced dimensional feature space called as fisherpalm. L.Shang et al. in [14] have used Independent Component Analysis (ICA) to extract the palm print features. Authors in [15] have used Locality Preserving Projection (LPP) method to obtain palm print features. Since sub space are constructed based on training data they need to be retrained if new persons enroll into the recognition system.

Coding based methods encode the responses of a bank of filters into bitwise feature code. Ajay Kumar et al. in [16] introduced a palm code method by using a Gabor filter to extract the local phase information of palm print. Gabor filters in four different orientations were used by D.Zhang et al. in [17] to generate four codes which were combined to get fusion code. In [18], Kong et al. proposed a competitive scheme to code the outputs of the elliptical Gabor filters with three different orientations. In [19], Sun et al. have presented an ordinal measure to code the outputs of the 2D Gaussian filters. Modified radon transformation to extract orientation feature is utilized by W. Jia et al. in [20]. Coding-based methods are reported to have good recognition accuracy, fast speed of feature extraction and matching but valuable information will be lost as only dominant orientations are used to extract features.

Statistical-based methods transform palm print images into another domain to compute features. Image transformation methods such as Fourier, Gabor and Wavelet transforms are used. Statistical approaches are categorized into local and global statistical approaches. In local statistical approach transformed image is divided into small regions and mean, variance of these regions are regarded as features in [21]-[24]. Global statistical approach computes moments, centre of gravity and density on the whole transformed image which are considered as the features in [25]-[28]. In addition to directly describing the local region by statistics, Wang et al. have used histogram of local binary pattern as features in [29].

Hand geometry features generally used are finger length and width, palm length and width, area/size of palm [30]-[33]. Principal lines are mainly used in palm print based recognition system that works in identification mode for categorizing palm print images into different categories to speed up the identification process. Common hand image acquisition set up use touch based design. In this type of acquisition set up individuals must place their hand on the sensor or a flat surface with or without pegs which makes the individuals to feel very uncomfortable during image acquisition and causes sanitary issues in public areas. These reasons greatly limit the applicability of the recognition systems developed using touch based acquisition set up for various commercial and civilian applications. Hence there exists greater demand for design of new types of biometric systems which uses unconstrained and contact free image acquisition set up.

## III. Proposed Work

The block diagram of the proposed verification system is shown in figure 1. This system works in three stages. First stage consists of image acquisition and preprocessing module. Second and third stage consists of feature extraction and recognition modules respectively. Preprocessing module employs image processing algorithms to locate key points on palm region of hand. Key points are used to find ROI (region of interest) of palm print. Feature extraction module extracts features of hand geometry and palm print by utilizing palm print ROI. Heart line features are extracted from the palm ROI. Finally the verification module utilizes minimum distance classifier according to Euclidean distance for confirming the identity as genuine or denying a person’s claimed identity as imposter. This process is done by comparing palm print query template with the palm print templates of claimed identity stored in the database during enrollment. Hand geometry and heart line shape features are used with palm print features to enhance the performance of verification system.

### *A. Image Acquisition and Preprocessing Module*

An image acquisition set up is designed to acquire hand images. A digital camera mounted on a tripod stand is focused against a black panel under normal room lighting conditions to capture hand image. The camera is placed at a suitable distance from the panel. During image acquisition

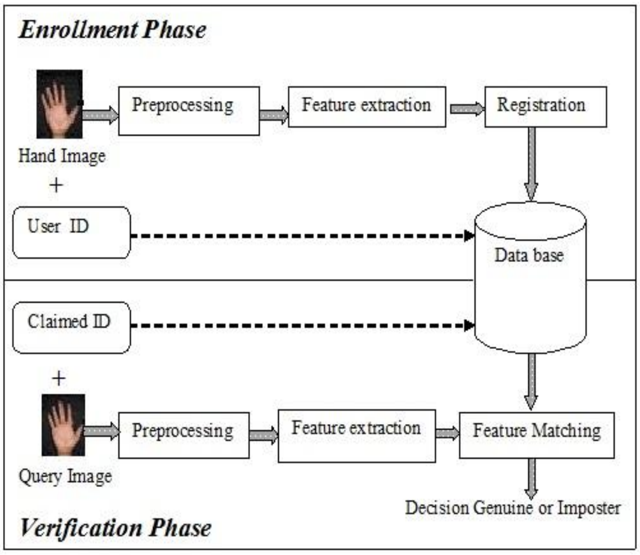


Fig. 1. Block diagram of proposed approach.

we requested the user to position their hand in front of the panel with the palmer side of the hand region facing the camera. There is no guidance or pegs to restrict the users hand placement. Our data collection process was carried out at two different locations which had no restrictions on surrounding illuminations. The data collection process spanned over two months and 448 persons volunteered for the database. Four hand images of each individual were captured in two sessions resulting in 8 images per individual leading to a total of 3584 images in the database. Complete image database is divided into two mutually exclusive gallery (training) and probe (test) sets. Let $DB_G$ = {$IG_1$, $IG_2$,……. $IG_N$ } be the gallery set database consisting of N hand images and $DB_P$ = {$QP_1$, $QP_2$,……. $QP_M$ } be the probe set database consisting of M hand images.

Pre processing process involves the following steps.

i. Captured color image is converted to gray level image.
ii. A fixed threshold is applied to convert the gray image into a binary image.
iii. Hand contour is obtained and three key points between finger valley positions are identified as per the algorithm proposed in [34]. Identified points $P_1$, $P_2$, $P_3$ are as shown in fig 2a.

ROI of palm print is the rectangle region selected using the points $P_1$ and $P_3$. The width of ROI is considered as the distance between $P_1$ and $P_3$ and top left corner of rectangular region is selected 20 pixels just below $P_1$. The ROI part containing the palm print is cropped out of the main image and then resized to a size of 125 X 125 pixels. The resized palm print ROI image undergoes no further pre processing. Identified palm print ROI and extracted ROI are shown in Fig. 2b and 2c respectively.

### *B. Feature Extraction*

To verify the identity of an individual, it is essential to store the individual's characteristic features extracted from the data acquired using image acquisition set up. Feature extraction algorithms are applied on the preprocessed input data to compute feature vectors. Instead of input data these feature vectors are stored in the data base and are called as templates.

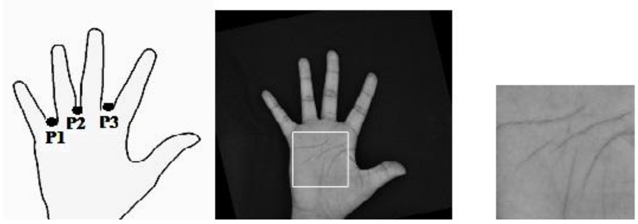


Fig. 2a. Key points. Fig. 2b. ROI Location. Fig. 2c. Palm ROI.

#### *1) Palm print feature extraction*

Local binary pattern (LBP) has been widely used to extract texture information from biometric images [35]. The local binary pattern operator transforms an image into an integer labels describing small-scale appearance of the image. The LBP operator assigns a binary label to every pixel in the image by thresholding it against the eight neighbor pixels. If the pixel's value is greater than the neighbor pixel value a value 1 is assigned, otherwise 0 is assigned. A binary label is called uniform if it consists of at most two bit-wise transitions from 0 to 1 or vice-versa. For example 11101111 and 11111101 are uniform binary labels whereas 10101111 and 01011011 are non-uniform. There are 58 labels of uniform patterns and the rest 198 labels are non-uniform. A label is given to each of the uniform patterns, and all other non-uniform patterns are assigned to a single label resulting in 59 labels. After all the labels have been determined, a histogram $H_l$ of the labels is constructed as

$$H_l = \sum \{ L(i,j) = l \} \quad l = 0, \ldots, p-1 \qquad (1)$$

Where p is the number of different labels produced by the LBP operator, i and j refer to the pixel location. LBP histogram calculated from palm print ROI are stored as feature vector of 59 dimensions. The matching of the palm print gallery and probe template is done by computing the distance between the two templates. The Euclidean distance metric is used as it achieves good results at low computational cost. Euclidean distance between two templates is defined as

$$d_p(P,G) = \sqrt{\sum_{i=1}^{59} (P_i - G_i)^2} \qquad (2)$$

where P and G are the templates to be compared. The larger the distance between the two templates the more dissimilar are the two images. At the verification stage a threshold T is used to regulate the system decision at matching stage. If the Euclidean distance is less than or equal to T, then the templates are considered to belong to the same individual else they are considered to belong to different individuals.

#### *2) Heart line shape identification*

Gabor filters have been widely used for extracting orientation information a 2D Gabor filter is defined as

$$G(x,y) = exp\left(-\frac{1}{2}\left(\frac{\acute{x}^2}{{\sigma_x}^2} + \frac{\acute{y}^2}{{\sigma_y}^2}\right)\right) \cdot \exp i2\pi f \acute{x} \qquad (3)$$

Where $\acute{x} = x \cdot \cos\theta + y \cdot \sin\theta$, $\acute{y} = -x \cdot \sin\theta + y \cdot \cos\theta$, f is the frequency of the sinusoid factor, $\theta$ is the orientation of the normal to the parallel stripes, and $\sigma_x$ and $\sigma_y$ are the standard deviation of the 2D Gaussian envelop.

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For identifying heart line shape following steps are used.

i. The palm print ROI image is convolved with a bank of Gabor filters sharing the same parameters, except the orientation parameter. Orientation along four directions 30, 45, 60 and 75 degrees are considered resulting in four different images.
ii. Sum of all the four images is computed.
iii. Morphological thinning operation is performed to reduce the line thickness. Gap between nearer lines are identified and are joined with isolated spikes being removed from the image.
iv. A line L is drawn between the end points of heart line and slope m of the line L is compued. Eight equi distance points are identified on the heart line ( $d_1$ to $d_8$).Lines ($l_1$ to $l_7$) are drawn between adajecnt equi diatance points and slope of lines $SL_i$ are computed. Deviation of the heart line from the line L is computed using

$$deviation = \frac{\sum_{k=1}^{7} (YC_i - YL_i)^2}{YL_i} \qquad (4)$$

where $YC_i$ is point on the curve and $YL_i$ is point on the line L.
v. If (deviation is less than 1)
then category = 1 (heart line is straight)
else if(deviation is greater than 4)
then category = 2 (heart line is curved)
else if ( the slope of lines $SL_1$ to $SL_5$ is less than 10)
then category = 3 (heart line is straight and slant)
else category = 4 (heart line is straight at start and little bit curved at end)

Category value is stored as shape feature vector of one dimension. Sample heart line shape for all the four categories are shown in figure 3.

*3) Hand geometry feature extraction*

Key points P1, P2 and P3 identified during pre processing stage are used for feature extraction. The angle between the line joining the points P1,P2 and P2,P3 is calculated. The angle value is stored as hand geometry feature vector of one dimension. In order to check the suitability of this feature, two hand images of the same person taken in two sessions were selected. The two angle values obtained were 151 and 156 degrees respectively. Two such sample images are shown in figure 4a and 4b. We observed that even though spacing between fingers are different there is not much difference in the angle values computed for first session and second session images. Let d(Tg,Tp) denote the difference value computed for pair of hand geometry templates, where Tg and Tp denotes gallery set and probe set templates respectively. For each individual Euclidean distance of every probe template with the four gallery set templates of

Fig. 3. Heart line shape category.

Fig 4a. Hand image of first session

Fig 4b. Hand image of second session

the same individual are computed. Mean value of distances for hand geometry feature is computed using the following equation

$$\mu_h = \frac{1}{n}\sum_{k=1}^{n} d_k \quad where \quad d_k = \sum_{i=1}^{4}\sum_{j=5}^{8} d(T_i, T_j) \qquad (5)$$

where $d(T_i, T_j)$ isthe Euclidean distance computed between templates $T_i$ *and* $T_j$ and n is the number of individuals considered. $\mu_h$ is computed by considering n value as 100.

## C. Verification Module

The task of verifying the claimed identity of an individual is considered as a two class classification problem with class label as Genuine and Imposter. A sequential rule is formulated for decision making purpose and steps carried out in this phase for verifying the claimed identity of an individual as either Genuine or Imposter are as follows.

i. For a query image q with claimed identity $I_q$ perform preprocessing and feature extraction procedure to get the query angle feature vector $T_{aq}$, heart line shape feature vector $T_{lq}$ and palm print feature vector $T_{pq}$.
ii. Retrieve the angle feature vector $T_{ap}$, heart line shape feature vector $T_{lp}$ and palm print feature vector $T_{pp}$ computed during enrolment for the identity $I_q$ (probe template) from the database.
iii. Compute Euclidean distance $d_p$ between and query palm print feature vector $T_{pq}$ and probe palm print feature vector $T_{pp}$.
iv. Let $d_l(T_{lq}, T_{lp})$ denote the comparison between pair of heart line feature templates. It is assigned with a value of 1 if both $T_{lq}$ and $T_{lp}$ values are same else is assigned with a value of 0.
v. Compute $d_a(T_{aq}, T_{ap})$ as the difference between the two angle feature vectors.
$d_a(T_{aq}, T_{ap}) = \|T_{aq} - T_{ap}\|$ where $\|\cdot\|$ denote the absolute value.
vi. If ( $d_p > T$ *and* $d_l == 1$ *and* $d_a \le \mu_h$ )
then label = Genuine
else label = Imposter

## IV. Experimental Results

In order to evaluate the performance of the proposed approach, verification experiments were conducted on the collected database. The performance of proposed system is measured using equal error rate(ERR) which is the value of false acceptance rate (FAR) for which FAR and false rejection rate (FRR) are equal. FAR is the percentage of authorized individuals that the biometric system fails to accept and FRR is the percentage of unauthorized individuals that the biometric system fails to reject. FAR and FRR are defined as

$$FAR = \frac{Number\ of\ accepted\ imposter\ claims}{Total\ number\ of\ imposter\ access} \times 100\% \qquad (6)$$

$$FRR = \frac{Number\ of\ rejected\ genuine\ claims}{Total\ number\ of\ genuine\ access} \times 100\% \qquad (7)$$

Threshold value of the system is obtained based on ERR criteria since both FAR and FRR must be as low as possible for the biometric system to work effectively. In the first experiment we investigated the performance of palm print trait. The result expressed as FAR and FRR depending on the threshold is plotted as shown in figure 5. When the decision threshold is adjusted to get low value for any one error rate the other will increase, since both are complementary to each other. Although geometry and line features do not vary much across different individuals they can still be used to verify the identity of individuals. Second experiment was carried out by combination of heart line shape feature with palm print feature. Third experiment was conducted considering angle feature along with the previous two features considered. Results obtained for both the experiments are plotted as shown in figure 6 and 7 respectively. The ERR value obtained for all the three experiments for verifying the identity of an individual are tabulated in Table 1. Results obtained clearly indicate that by using more than one trait for verifying the identity, ERR can be reduced. Also with respect to verification scheme major work reported in literature is with images being acquired using scanners and pegs being used to fix the placement of hand. Where as in our work we have captured images under normal room lighting conditions and major challenge is in extracting features which are invariant to illumination. Proposed system with ERR of 2.53% is able to achieve similar performance to that reported in [36] which uses a contactless image acquisition setup with ERR of palm print verification being 2.16%.

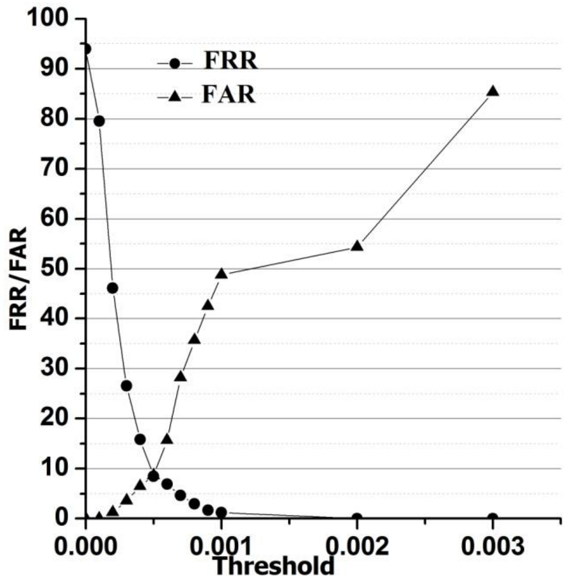


Fig. 5. Dependency of FAR and FRR on the threshold value for palm print.

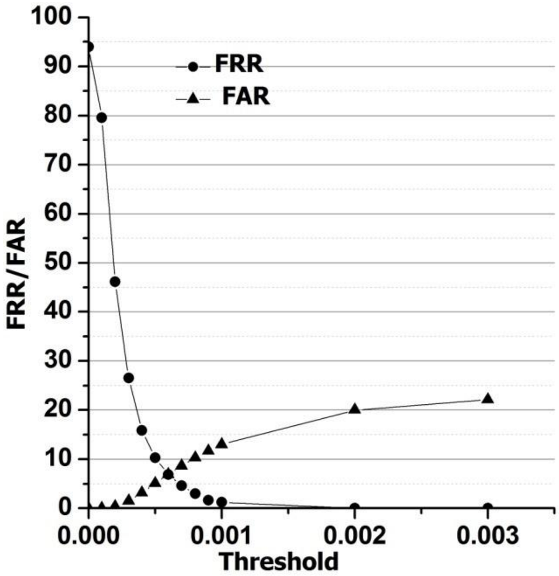


Fig. 6. Dependency of FAR and FRR on the threshold value for palm print and heart line shape feature.

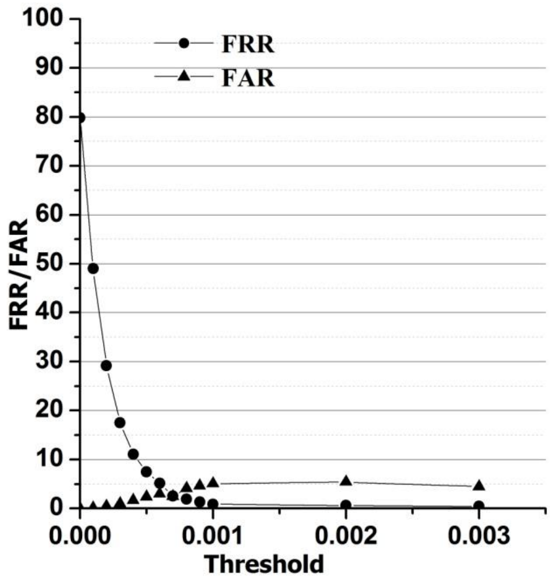


Fig. 7. Dependency of FAR and FRR on the threshold value for palm print, Herat line shape and Angle feature.

TABLE 1
Verification performance of the proposed approach.

| Biometric trait used | ERR |
|---|---|
| Palm print | 9.52% |
| Palm print + Heart line shape feature | 6.8% |
| Palm print +Heart line shape + Angle feature | 2.53% |

## V. CONCLUSIONS

In this work, we have proposed an approach for biometric verification system based on palm region features. The proposed approach is of significance since all the three traits can be extracted from the palmer region of the hand with the images being acquired with a contactless image acquisition set up. The proposed system is reliable for medium range

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security applications as it achieves an ERR of 2.53%. The objective of this work was to investigate the integration of palm print, heart line and geometry features to achieve better performance that may not be achievable with using unimodal biometric traits. Compared to the other related work reported in literature proposed system is able to achieve similar performance with less number of traits and with low dimensional features. Although the ERR of verification system that uses contactless acquisition set up is more when compared to that of contact based, contactless acquisition set up which is hygienic can make the verification system more flexible and expand the application of the verification system. Further investigation of this work includes identifying other hand related traits and investigating how well the identified traits reduce the ERR. By reducing ERR security level of the system can be enhanced.

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