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Fingerprint Recognition- A Proposed Method

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Abstract:
Fingerprints are a great source for identification of individuals. Fingerprint recognition is one of the oldest forms of biometric identification. However recognition of fingerprint is not always easy. The objective of this paper is to provide a way for fingerprint recognition using minutiae extraction. The factors relating to obtaining high performance feature point detection algorithm, such as image quality, segmentation, image enhancement and feature detection. Commonly used features for improving fingerprint image quality are Fourier spectrum energy, Gabor filter energy and local orientation. Accurate segmentation of fingerprint ridges from noisy background is necessary. For efficient enhancement and feature extraction algorithms, the segmented features must be void of any noise. Most fingerprint recognition techniques are based on minutiae matching. However, these suffers from problems associated with the handling of poor quality impressions. One problem of fingerprint matching is distortion. Distortion changes both geometric position and orientation, and leads to difficulties in establishing a match among multiple impressions acquired from the same fingertip. Marking all the minutiae accurately as well as rejecting false minutiae is another issue still under research. The proposed work has combined existing methods to build a minutia extractor and a minutia matcher. The combination of multiple methods comes from a wide investigation into research papers. Also some novel changes like segmentation using Morphological operations, improved thinning, false minutiae removal methods, minutia marking with special considering the triple branch counting, minutia unification by decomposing a branch into three terminations, and matching in the unified x-y coordinate system after a two-step transformation are used in the work.

Keywords: fingerprint matching; pattern-based method; minutiae-based method;

I. INTRODUCTION

The quality of fingerprint images and extraction of minutiae have an important role in the performance of automatic identification and verification. In general, the minutiae extraction algorithm starts with a preprocessing for improving the quality of images without changing the local and global properties of the image. The fingerprint image can be characterize by the features as core and delta or as minutiae represent the end of ridge or the bifurcation .The methods based on minutiae are sensitive to this stage.Any missing minutiae or false minutiae can degrade the performance of the matching algorithm. Many techniques are proposed an effective method for enhancement based on Gabor filters. Gabor filters have both frequency ridge and orientation ridge properties.The frequency ridgedepends on orientation ridges. Some researchers proposed an efficient implementation of contextual filtering based on short-time Fourier transform (STFT) that requires partitioning the image into small overlapping blocks and performing Fourier analysis separately on each block[1-2]. The orientation, frequency and mask region of image are all simultaneously estimated .Theseveral approaches to automatic minutiae extraction are two categories techniques, there are different from one other. The most of these methods transform fingerprint images into binary images, the images obtained are submitted to a thinning process which allows for the ridge line thickness to be reduced to one pixel finally, a simple image scan allows for locating the pixels that correspond to minutiae. On the other hand, other techniques are based on ridge line, where the minutiae are extracted directly from gray images[3]. Literature Review In biometrics, fingerprint is recognized as the most common modality among all biometric characteristics that have been studied so far [1], [2]. The advantages of the fingerprint could be attributed to several factors: 1) fingerprint pattern is stable and invariant which completely satisfies the requirement of uniqueness for being a biometric modality and 2) the use of fingerprint is also acceptable to people in comparison with other kinds of biometric modalities [3], [4], [2]. Therefore, besides the traditionally official applications, fingerprint also being adopted in civilian area since its study in modern biometrics had been proposed the 1960s [5], [6]. For instance, the automatic fingerprint identification system (AFIS) can be easily found in office buildings, and some similar applications are also provided on the laptop computers, smart phones, etc. The performance of these applications largely depends on the reliability of features extracted from the sensed fingerprint image. Existing studies have shown that fingerprint quality is significant to the reliability of the features [7]. A fingerprint, as a common sense, is composed of two kinds of lines namely fingerprint ridge and valley [6] which alternately run on the fingertip surface. The discontinuous flowing of ridge lines generate two types of minor features known as ridge ending and ridge bifurcation which are categorized as the minutiae points [8]. Matching algorithms of fingerprint mainly use minutiae-based features, particularly restricted to these two types of minutiae points [8], [2]. The accuracy of a matching algorithm therefore depends on the reliability of the detected features of fingerprint images. However, these features could be easily affected by noisy inform*ation contained in the image, such as noise pixels and abrupt break of ridge lines caused by tiny wrinkles. In addition to such impacts, there are also some additional factors that influence the reliability and precision of the extracted features, and hence reflect the quality of fingerprint images [9]. For these reasons, earlier studies chose to improve the reliability of detected features via post processing [8] or to improve the quality of fingerprint images with enhancement and other preprocessing approaches [10], [8], [11], [12]. Figure 1 shows examples of the effect of enhancement (fig. 1c and 1e) and noises (fig. 1b and 1d) to matching results. As a result, fingerprint recognition systems employ quality control to guarantee the quality of captured samples [14]. Alternatively, matching algorithm for low quality image could also be implemented via other features rather than minutiae points [15], [16]. Furthermore, recent studies pay attention to high resolution image which is able to provide higher quality image, and the level-3 features could be available for more secure applications [17]. This paper chiefly discusses quality assessment of the gray-level fingerprint images, which has been the main focus of most of the existing studies [18].

II. PROPOSED METHOD

Skin on human fingertips contains ridges and valleys which together forms distinctive patterns. These patterns are fully developed under pregnancy and are permanent throughout whole lifetime. Prints of those patterns are called fingerprints. Injuries like cuts, burns and bruises can temporarily damage quality of fingerprints but when fully healed, patterns will be restored. Through various studies it has been observed that no two persons have the same fingerprints, hence they are unique for every individual. A fingerprint image is shown in figure 1.

Figure.1. Fingerprint Image

A fingerprint recognition system constitutes of fingerprint acquiring device, minutiaextractor and minutia matcher as shown in figure 2.

Figure .2. Fingerprint Recognition System

For fingerprint acquisition, optical or semi-conduct sensors are widely used. They have high efficiency and acceptable accuracy except for some cases that the user's finger is too dirty or dry. The minutia extractor and matcher modules have been explained in detail in the next part for algorithm design and other subsequent sections. To implement a minutia extractor, a three stage approach is widely used by Researchers. They are pre-processing, minutia extraction and post processing stage. For the fingerprint image pre-processing stage, Histogram Equalization and Fourier Transform have been used to do image enhancement. And then the fingerprint image is binarized using the locally adaptive threshold method. The image segmentation task is fulfilled by a three-step approach: block direction estimation, segmentation by direction intensity and Region of Interest extraction by Morphological operations. For minutia extraction stage, iterative parallel thinning algorithm is used. The minutia marking is a relatively simple task. For the post processing stage, a more rigorous algorithm is developed to remove false minutia. Also a novel representation for bifurcations is proposed to unify terminations and bifurcations. The minutia matcher chooses any two minutiae as a reference minutia pair and then matches their associated ridges first. If the ridges match well, the two fingerprint images are aligned and matching is conducted for all remaining minutia. The following flowchart, as shown in figure 3, will illustrate the entire process.

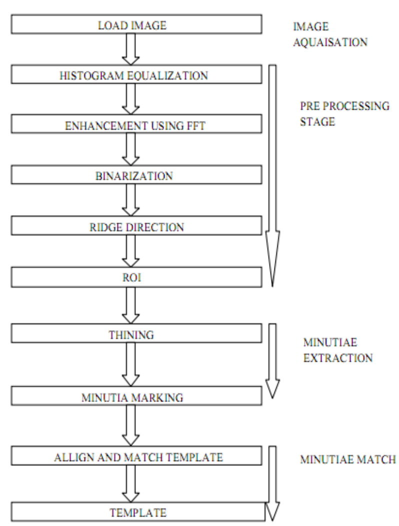
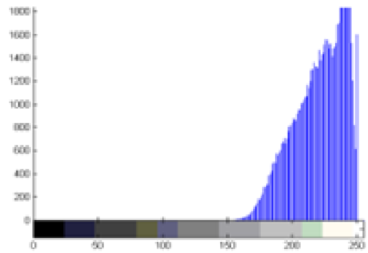
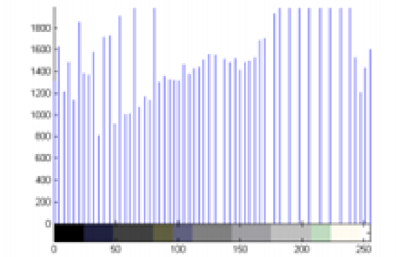


Figure. 3. Flowchart for Finger print Recognition System

The first step in the minutiae extraction stage is Fingerprint Image enhancement. This is mainly done to improve the image quality and to make it clearer for further operations. Often fingerprint images from various sources lack sufficient contrast and clarity. Hence image enhancement is necessary and a major challenge in all fingerprint techniques to improve the accuracy of matching. It increases the contrast between ridges and furrows and connects the some of the false broken points of ridges due to insufficient amount of ink or poor quality of sensor input.There are three techniques: Histogram Equalization, Fast Fourier Transformation and Image Binarization. Histogram equalization is a technique of improving the global contrast of an image byadjusting the intensity distribution on a histogram.This allows areas of lower local contrast to gain a higher contrast without affecting the global contrast. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values. The original histogram of a fingerprint image has the bimodal type as shown in Figure 4 (a), the histogram after the histogram equalization occupies all the range from 0 to 255 and the visualization effect is enhanced as shown in Figure 4 (b). The original image and image after enhancement are shown in figure 5.



(a)



(b)

Figure 4 (a) Histogram of an image **Figure 4 (b) Histogram equalization of an image**

Figure 5(a) Original image

Figure 5 (b) Enhanced Image after Equalization

The image was divided into small processing blocks (32 by 32 pixels) and the Fouriertransform was performed according to:

$$F(u,v) = \sum \sum f(x,y) \times \exp\left\{-j2\pi \times \left(\frac{ux}{M} + \frac{vy}{N}\right)\right\} \quad 1.1$$

for u = 0, 1, 2, ..., 31 and v = 0, 1, 2, ..., 31.

In order to enhance a specific block by its dominant frequencies, the FFT of the block was multiplied by its magnitude a set of times.Where the magnitude of the original FFT = abs (F(u ,v)) = |F(u ,v)|.

The enhanced block is obtained according to:

$$g(x,y) = F^{-1}\left\{F(u,v) \times |F(u,v)|^k\right\} \quad 1.2$$

Where $F^{-1}(F(u,v))$ is done by:

$$f(x,y) = \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} F(u,v) \times \exp\left\{j2\pi \times \left(\frac{ux}{M} + \frac{vy}{N}\right)\right\} \quad 1.3$$

for x = 0, 1, 2, ..., 31 and y = 0, 1, 2, ..., 31.

The k in formula (1) is an experimentally determined constant, which was k=0.45 to calculate. While having a higher "k" improves the appearance of the ridges, filling up small holes in ridges, having too high a "k" can result in false joining of ridges. Thus a termination might become a bifurcation. The original image and its enhancement by FFT are present in figure 6.

Figure 6 (a) Original image

Figure 6(b) Image Enhancement by FFT

The enhanced image after FFT has the improvements to connect some falsely brokenpoints on ridges and to remove some spurious connections between ridges. Fingerprint Image Binarization is to transform the 8-bit Gray fingerprint image to a 1-bit image with 0-value for ridges and 1-value for furrows. After the operation, ridges in the fingerprint are highlighted with black colour while furrows are white. A locally adaptiveBinarization method is performed to binarized the fingerprint image. Such a named method comes from the mechanism of transforming a pixel value to 1 if the value is larger than the mean intensity value of the current block (16x16) to which the pixel belongs. These are shown in figure 7.

Figure.7. (a) Enhanced image

Figure .7. (b) Image after Binarization

In general, only a Region of Interest (ROI) is useful to be recognized for each fingerprintimage. The image area without effective ridges and furrows is first discarded since it only holds background information. Then the bound of the remaining effective area is sketched out since the minutia in the bound region is confusing with those spurious minutia that are generated when the ridges are out of the sensor. To extract the ROI, a two-step method is used. The first step is block direction estimation and direction variety check, while the second is intrigued from some Morphological methods.
The direction for each block of the fingerprint image with W *W in size(W is 16 pixels by default)is estimated. The algorithm is:

- The gradient values along x-direction (gx) and y-direction (gy) for each pixel of the block is calculated. Two Sobel filters are used to fulfill the task.
- For each block, following formula is used to get the Least Square approximationof the block direction for all the pixels in each block.

$$\tan\beta = \frac{2\sum\sum(g_x * g_y)}{\sum\sum(g_x^2 - g_y^2)} \qquad 1.4$$

Figure 8(a) Binarization image

The formula is easy to understand by regarding gradient values along x-direction and y direction as cosine value and sine value. So the tangent value of the block direction is estimated nearly the same as the way illustrated by the following formula.

$$\tan 2\theta = \frac{2\sin\theta \cdot \cos\theta}{(\cos^2\theta - \sin^2\theta)} \qquad 1.5$$

After the estimation of each block direction, those blocks without significant information on ridges and furrows are discarded based on the following formulas:

$$E = \{2\sum\sum(g_x * g_y) + \sum\sum(g_x^2 - g_y^2)\}/W * W\sum\sum(g_x^2 + g_y^2) \qquad 1.6$$

For each block, if its certainty level E is below a threshold, then the block is regardedas a background block. The direction map is shown in the following diagram figure 8(assuming there is only one fingerprint in For each block, if its certainty level E is below a threshold, then the block is regarded each image.)

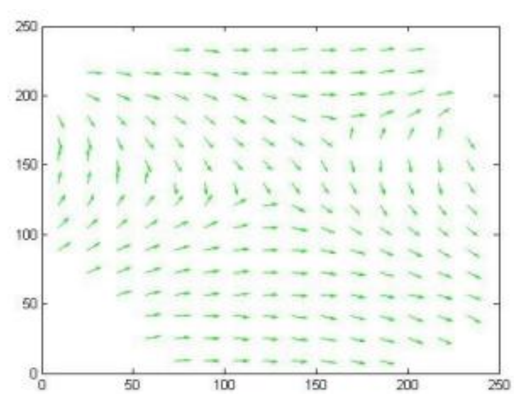
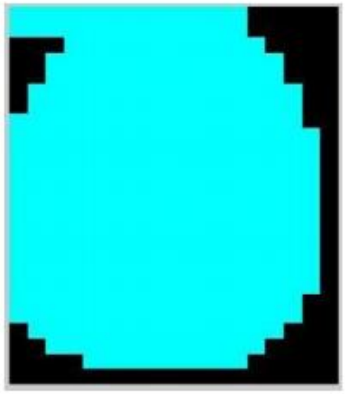
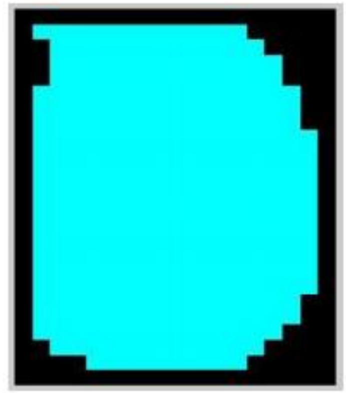


Figure 8(b) Direction Map

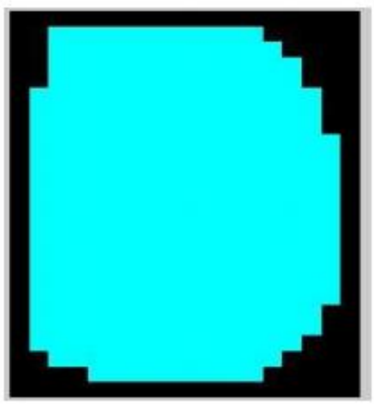
Two Morphological operations called 'OPEN' and 'CLOSE' are adopted. The 'OPEN' operation can expand images and remove peaks introduced by background noise figure 9 (c). The 'CLOSE' operation can shrink images and eliminate small cavities in Figure 9 (b).



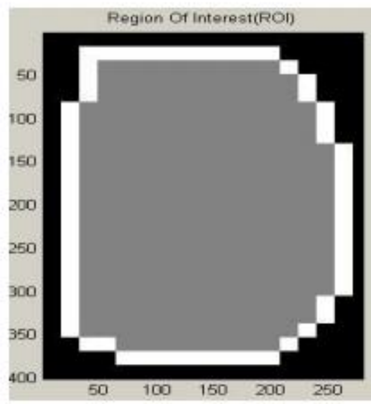
(a)



(b)



(c)



(d)

Figure 9 (a) Original Image, (b) Close Operation, (c) Open Operation, (d) ROI+Bound

Figure (d) show the interest fingerprint image area and it's bound. The bound is the subtraction of the closed area from the opened area. Then the algorithm throws away those leftmost, rightmost, uppermost and bottommost blocks out of the bound so as to get the tightly bounded region just containing the bound and inner area. Ridge Thinning is to eliminate the redundant pixels of ridges till the ridges are just one pixel wide. An iterative, parallel thinning algorithm is used. In each scan of the full fingerprint image, the algorithm marks down redundant pixels in each small image window(3x3). Finally removes all those marked pixels after several scans. The thinned ridge map is then filtered by other three Morphological operations to remove some H breaks, isolated points and spikes. Figure 10 shows ROI and thinned image

Figure 10 (a) ROI

Figure 10 (b) Thinned Image

After the fingerprint ridge thinning, marking minutia points is relatively easy. The concept of Crossing Number (CN) is widely used for extracting the minutiae [6]. In general, for each 3x3 window, if the central pixel is 1 and has exactly 3 one-value neighbors, then the central pixel is a ridge branch as shown in figure 11(a). If the central pixel is 1 and has only 1 one-value neighbour, then the central pixel is a ridge ending figure 11 (b) ,i.e., if Cn(P) = =1 it's a ridge end and if Cn(P) = = 3 it's a ridge bifurcation point, for a pixel P.

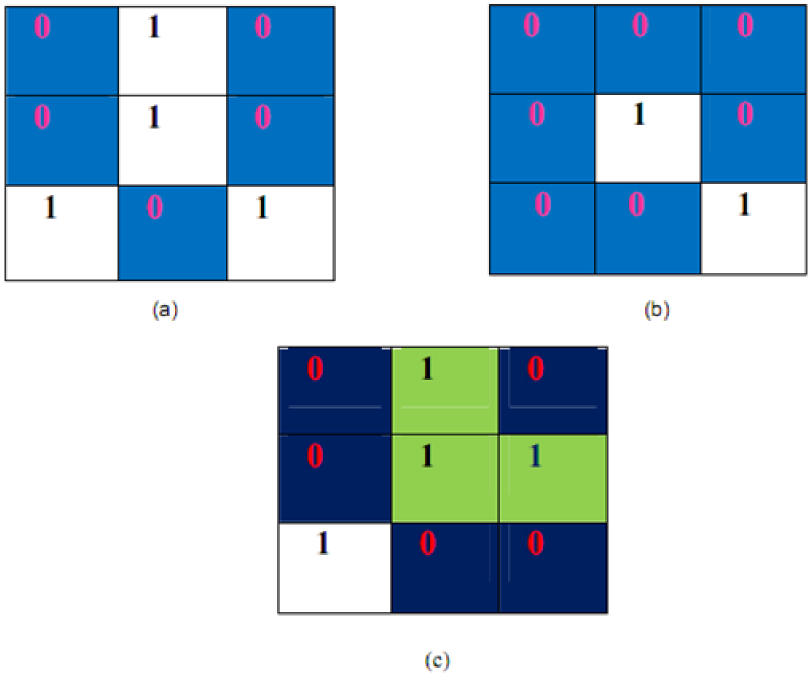


Figure.11.(a) Bifurcation, (b) Termination, (c) Triple Counting Branch

Figure 11 (c) illustrates a special case that a genuine branch is triple counted. Suppose both the uppermost pixel with value 1 and the rightmost pixel with value 1 have anotherneighbour outside the 3x3 window, so the two pixels will be marked as branches too. Butactually only one branch is located in the small region. So a check routine requiring that none of the neighbors of a branch are branches is added. Also the average inter-ridge width D is estimated at this stage. The average inter ridge width refers to the average distance between two neighboring ridges. The way to approximatethe D value is to scan a row of the thinned ridge image and sum up all pixels in the row whose value is one. Then divide the row length with the above summation to get an inter ridge width. For more accuracy, such kind of row scan is performed upon several other rows and column scans are also conducted, finally all the inter-ridge widths are averaged to get the D. Together with the minutia marking, all thinned ridges in the fingerprint image arelabelled with a unique ID for further operation. The labelling operation is realized by using the Morphological operation. Minutiae extraction from thinned image as shown in figure 12 (a) and **Figure 12(b).**

Figure 12 (a) Thinned Image

Figure 12 (b) Minutiae Extraction

At this stage false ridge breaks due to insufficient amount of ink & ridge crossconnections due to over inking are not totally eliminated. Also some of the earlier methodsintroduce some spurious minutia points in the image. So to keep the recognition systemconsistent these false minutiae need to be removed. Here we first calculate the inter ridge distance D which is the average distance between two neighbouringridges. For this scan each row to calculate the inter ridge distance using theformula:

$$\text{Inter ridge distance} = \frac{\text{sum of all pixel with value 1}}{\text{row length}}$$

Finally an averaged value over all rows gives D.

All we label all thinned ridges in the fingerprint image with a unique ID for furtheroperation using a MATLAB morphological operation BWLABEL. Now the following 7 types of false minutia points are removed using these steps as shown in figure 13.

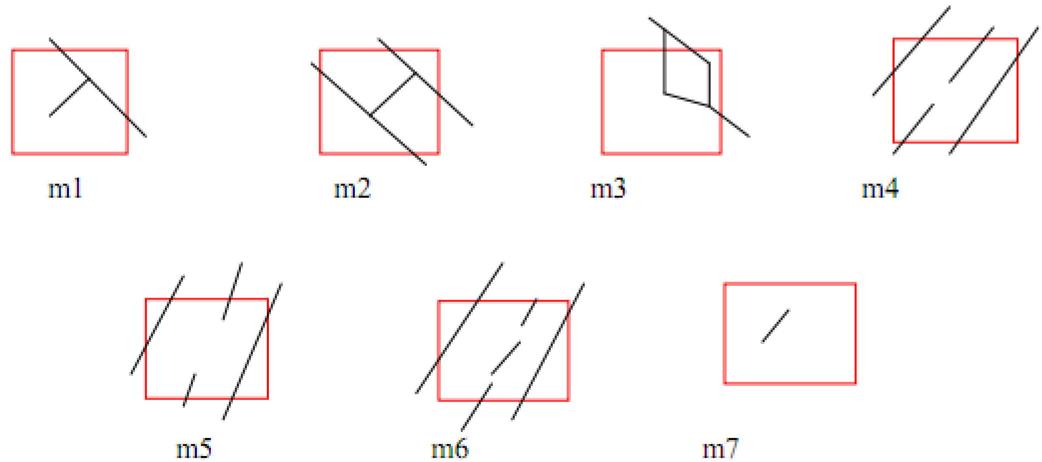


Figure.13.False Minutia Points

The following steps illustrates the formation of seven figures as shown in figure 13.

1. If d(bifurcation, termination) < D & the 2 minutia are in the same ridge then remove both of them (case m1)
2. If d(bifurcation, bifurcation) < D & the 2 minutia are in the same ridge them removeboth of them (case m2, m3)
3. If d(termination, termination) ≈ D & the their directions are coincident with a small angle variation & no any other termination is located between the two terminations then remove both of them (case m4, m5, m6)
4. If d(termination, termination) < D & the 2 minutia are in the same ridge then remove both of them (case m7)

Since various data acquisition conditions such as impression pressure can easilychange one type of minutia into the other, most researchers adopt the unification representation for both termination and bifurcation. So each minutia is completely characterized by the following parameters at last: 1) x-coordinate, 2) y-coordinate, and 3) orientation. The orientation calculation for a bifurcation needs to be specially considered. All three ridges deriving from the bifurcation point have their own direction. The bifurcation is broken into three terminations. The three new terminations are the three neighbour pixels of the bifurcation and each of the three ridges connected to the bifurcation before is now associated with a termination respectively.

III. CONCLUSIONS

The paper presents Fingerprint Recognition as a form of biometric to recognize identities of human beings. It includes all the stages from enhancement to minutiae extraction of fingerprints. There are various standard techniques are used in the intermediate stages of processing. The relatively low percentage of verification rate as compared to other forms of biometrics indicates that the algorithm used is not very robust and is vulnerable to effects like scaling and elastic deformations. In this paper we have combined many methods to build a minutia extractor and a minutia matcher. The following concepts have been used segmentation using Morphological operations, minutia marking by specially considering the triple branch counting, minutia unification by decomposing a branch into three terminations.

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