AN EFFICIENT BINARIZATION TECHNIQUE FOR FINGERPRINT IMAGES

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ABSTRACT
Fingerprint identification is the most prominent method of biometric identification. Here, fingerprint is a widely used form of biometric identification and is robust means of person identification. In this, a set of minutiae points were considered and which characterize the fingerprints by extracting minutiae points from fingerprint under uncontrolled situation and it is a robust binarization process is considered to get correct set of minutiae points. In this, a rough-set based approach for binarization of fingerprint image is presented and maximization of rough entropy and minimization of roughness of the fingerprint images lead to an optimum threshold for binarization. Experimental results show that the proposed method for extracting minutiae is fairly efficient and fast compared to previous method.

Keywords: Fingerprint Images, Rough Set, Binarization, Rough entropy, Minutiae points.

I. INTRODUCTION
The recent advances of information technologies and the increasing requirements for security have led to a rapid development of automatic personal identification systems based on biometrics. Fingerprint is a widely used form of biometric identification. It is a robust means of person identification. The fingerprint of an individual is unique and remains unchanged over a lifetime. A fingerprint is formed from an impression of the pattern of ridges on a finger. A ridge is defined as a single curved segment, and a valley is the region between two adjacent ridges. The minutiae, which are the local discontinuities in the ridge flow pattern, provide the features that are used for identification. Details such as the type, orientation, and location of minutiae are taken into account when performing minutiae extraction. Fingerprint matching is among the most important and reliable methods for the identification of a person.

There are two main applications involving fingerprint matching: fingerprint verification and fingerprint identification [1]. While the goal of fingerprint verification is to confirm the identity of a person, the goal of fingerprint identification is to establish the identity of a person. In general, fingerprint identification involves comparing a query fingerprint with a large number of fingerprints stored in a database, which is time consuming. To reduce search time and lower computational complexity, fingerprint classification is often employed to partition the database into smaller subsets. Fingerprint recognition has forensic applications like criminal investigation, missing children etc., government applications like social security, border control, passport control, driving license etc., and commercial applications like e-commerce, internet access, ATM, credit card etc. Because of their uniqueness and consistency over the time, fingerprints have been used for identification and verification over a century [2]. The process of fingerprint recognition is becoming automated and results in many AFIS (Automatic Fingerprint Identification System).

Fingerprint matching depends on the comparison of characteristics of the local ridges and their relationships to the local ridge's characteristics, called minutiae in automatic fingerprint identification systems (AFIS), are ridge terminations and bifurcations. Automatic minutiae extraction is an extremely critical process in AFIS. Though several approaches for the minutiae detection have been proposed in literatures, most of these methods are carried out on thinned images. As a result of a thinning process, some ridge smoothing and postprocessing are often needed to eliminate many spurious minutiae occurring due to the presence of undesired spikes and breaks. The process of fingerprint recognition system consists of three main parts: fingerprint image preprocessing, feature extraction, and matching. Components such as noise cleaning, binarization and thinning are included in as preprocessing [2]. After noise cleaning, binarization is used to convert a gray scale image into binary image. Binarization is important as most of the feature extraction algorithms included in AFIS work on binary image instead of gray scale image. For efficient feature extraction thinning is done after binarization and features are extracted from the skeleton image. Features are extracted in the form of minutiae points. Minutiae are local discontinuities in the fingerprint pattern and fingerprint identification usually depends on the location and direction of these minutiae points i.e., ridge ending and bifurcation (merging and splitting) along the ridge path. These minutiae points are then matched for identification or verification process. Figure 1 shows the examples of minutiae.

II. PROPOSED METHOD
Fingerprint image identification and matching are the most important areas in digital image processing. Fingerprint identification is the most prominent method of biometric identification. The contrast of the
The fingerprint image is a significant one for a reliable matching process. The quality of the image can be enhanced at the preprocessing stage of image processing [3]. The method presented in this deals only with the first step in the fingerprint recognition system. Preprocessing is an important component of Fingerprint recognition system because quality of image plays a major role in the performance of the system. As most of the feature extraction algorithms work on binary images instead of gray scale and also the results of feature extraction depend upon the quality of binary image used, an efficient binarization of fingerprint image is highly necessary [3]. The erroneous binarization of fingerprint images may lead to incorrect location and direction of minutiae points and thus reducing the overall performance of AFIS. This is concentrated on fingerprint image binarization. In particular, a rough set based approach for fingerprint binarization is proposed and it results in an optimum threshold value for binarization. The threshold is set for the gray level values. As the gray level is a value without any unit hence the threshold set for it is also unit free. The results obtained are encouraging and this stage consists of lightening and smoothing processes.

An accurate representation of the fingerprint image is critical to automatic fingerprint identification systems, because most deployed commercial large-scale systems are dependent on feature-based matching. Fingerprint feature extraction phase is classified into two categories namely: local and global features. The proposed rough set based binarization process, the concept of Rough-set Theory was given by Pawlak [4]. Rough-set theory has become a popular tool for generating logical rules for classification and prediction. It is a mathematical tool to deal with vagueness and uncertainty and the focus of the rough-set theory is on the ambiguity of objects. A Rough-set is a set with uncertainties in it i.e. some elements may or may not be the part of the set. Rough-set theory uses approximation for these rough-sets. A rough-set can be defined in terms of lower and upper approximations. The uncertainties at object boundaries can be handled by describing different objects as Rough-sets with lower (inner) and upper (outer) approximations. Figure 2 shows the object present along with its lower and upper approximation. Consider an image as a collection of pixels. This collection can be partitioned into different blocks (granules) which are used to find out the object and background regions. From the roughness of these regions rough entropy is computed to obtain the threshold.

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A. Granulation
Granulation involves decomposition of whole image into parts. In this, image is divided into blocks of different sizes. These blocks are termed as Granules. For this decomposition quad-tree representation of the image is used and quad-trees are most often used to partition a two dimensional space by recursively subdividing it into four quadrants or regions. Each region is subdivided on the basis of some conditions. In this case following condition has been used for the decomposition. For a block B if 90 % or more of pixels are either greater than or less than some predefined threshold, the block is not split. Let \( x_i \), \( i = 1, 2, \ldots, n \) be pixel values belonging to block B. The block B is not split if, 90% of \( x_i \leq T \) or \( x_i \geq T \), where T is a pre-specified threshold. The block B is otherwise split. Figure 3 shows the quad-tree granules obtained from a fingerprint image. In this, 90% of the pixels are of same range implies the block as homogeneous otherwise the variation in intensity values compelled to split the block unless only homogeneous blocks are left.
B. Object-Background Approximation

Once the image is split in granules, then is to identify each granule as either object or background. The image is divided into granules based on some criteria. Let G be the total number of granules then problem is to classify each granule as either object or background. At this point there is a need to know the dynamic range of the image. Let \([0, L]\) be the dynamic range of the image. Our final aim is to find a threshold \(T, 0 \leq T \leq L-1\), so that the image could be binarized based on threshold \(T\).

Granules with pixel values less than \(T\) characterize object while granules with values greater than \(T\) characterize background. After getting this separation, object and background can be approximated by two sets as follows.

**The lower approximation of the object or background:** For all blocks belonging to object (background), the blocks having pixels with same intensity values are called lower (inner) approximations of object (background).

**The upper approximation of the object or background:** All blocks belonging to object (background) also belong to upper approximation of the object (background).

From this approximation, the roughness of each granule needs to be computed.

C. Roughness of Object and Background

Roughness of object and background is computed as described in [5]. Here defining the terms and detailed explanation can be obtained. The roughness of object is

\[
R_o = 1 - \frac{|O_u|}{|O_l|}
\]

(1)

Here \(O_u\) and \(O_l\) are cardinality of object upper approximation and lower approximation respectively. Similarly roughness of background can be defined as

\[
R_b = 1 - \frac{|B_u|}{|B_l|}
\]

(2)

Where, \(B_u\) and \(B_l\) are cardinality of background upper approximation and lower approximation respectively. Roughness is a measure of uncertainty in object or background. It can be obtained as the number of granules out of total number of granules that are certainly not the members of the object or background. Thus the value of the roughness depends on the threshold value (T) used to obtained the lower and upper approximation of the object or background. The rough entropy can be measured on the basis of above two roughnesses.

**D. Rough Entropy Measure**

A measure called Rough entropy based on the concept of image granules is used as described in [6]. Rough entropy is computed from object and background roughness as

\[
R_e = -\frac{1}{2} \left[ R_o \log R_o + R_b \log R_b \right]
\]

(3)

Here, \(R_o\) is the object roughness and \(R_b\) is the background roughness. Maximization of rough-entropy measure minimizes the uncertainty i.e., roughness of object and background. The optimum threshold is obtained as it maximises the rough entropy [7].

**E. Algorithm for Binarization**

Images are then processed stepwise to get their binarized form. Following are the steps for the binarization of image as proposed.

1. Represent the image in the form of quad–tree decomposition.
2. For a threshold value \(T, 0 < T \leq 255\), separate the blocks obtained from decomposition into object and background.
3. Find lower and upper approximation of object and background.
4. Compute object and background roughness and can find out rough entropy.
5. Repeat steps 2 to 4 for all values of \(T\), i.e. from \(T=1\) to \(255\).
6. The value of \(T\) for which Rough entropy is maximum, is selected as a threshold for binarization.
7. Binarize the image using optimum threshold obtained.
IV. SIMULATION RESULTS

To demonstrate the proposed method, it is tested on natural images as well as on a set of fingerprint images. Otsu’s algorithm of binarization which is regarded as most popular has also been applied on the set of fingerprint images. The other existing algorithms of binarization have not been considered here and Otsu’s method is selected as it is widely used in the community [8]. The comparison of the results of proposed method with that of the Otsu’s method has been performed and can calculated roughness of object and background. Results of these algorithms have been compared with visual inspection as seen in figure 5. It is observed that the present algorithm works better for the fingerprint images[9].

Results of fingerprint images are presented in figures. One of the images used has text in it and there by having non linear edges. Another image is of a building consisting of mostly vertical and horizontal edges. The results obtained by both algorithms appear to be almost similar. Represent the image in the form of quad-tree decomposition. For a threshold value ‘T’, 0 < T ≤ 255, separate the blocks obtained from decomposition into object and background. The method is finally tested on many fingerprint images to show that it can deal with the special structure of the fingerprint. Some examples of the binarization of the fingerprint images by Otsu’s method and rough-set based method are shown in these figures. Otsu’s method works with an assumption that the image under consideration is almost bimodal whereas proposed rough-set based approach does not have any such assumption at the outset. This assumption could make this method more attractive for the users. The image histogram is mostly bi-modal and selects the threshold in between two peaks.

Number of attempts has been made to quantitatively compare the otsu’s method with that of the proposed rough set based method, the best threshold for any image which has multimodal histogram as shown in figure 8. Visually, it could be observed that rough-set based method provides equivalent,better results compare to otsu’s method. Binarize the fingerprint image using optimum threshold.
For the sake of completeness, the threshold obtained for all images by both the methods have been implemented. However, by looking at the threshold only, it is quite easy to recognize that proposed method performs better and efficient.

CONCLUSION

In this work, it is introduced a rough set based binarization for fingerprint images and this method avoids assumption that images are mostly bimodal whereas the same assumption is the basis for widely used binarization technique such as otsu’s binarization method. The results obtained appear to be equivalent and better than the existing otsu’s technique. Ideally the method can be compared with the other fuzzy based approaches, frequency based approaches, but it has not been included here as otsu’s method for binarization is considered as widely used method. The proposed method is that it may leads to a good binarization in case the fingerprint image quality is very good quality. A good noise cleaning algorithm be presented by this process of binarization. Noted that the proposed method is efficient and simple than otsu’s method. In the future, proposed method for binarization could be extended to classify the image pixels in more than two classes and could implement for other images also.

REFERENCES