Detection and Rectification of Distorted Fingerprints

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***Abstract** - False non-match between fingerprints is majorly caused due to elastic distortion of fingerprints. This problem may affect all fingerprint recognition applications but it is especially dangerous in negative recognition applications, such as watch-list and reduplication applications. In such applications, malicious users may purposely distort their fingerprints to escape identification. In this paper, we proposed a new algorithms to detect and rectify skin distortion based on a single fingerprint image. Distortion detection is viewed as a two-class classification problem, for which the registered ridge orientation map and period map of a fingerprint are used as the feature vector and a SVM classifier is trained to perform the classification task. Distortion rectification (or equivalently distortion field estimation) is viewed as a regression problem, where the input is a distorted fingerprint and the output is the distortion field. To solve this problem, a database of various distorted reference fingerprints and corresponding distortion fields is built in the off-line stage, and then in the stage which is online , the nearest neighbor of the input fingerprint is found in the database which we referred and the corresponding distortion field is used to transform the input fingerprint into a normal one. We have obtained promising results three databases which contained a huge number of distorted fingerprints.*

Keywords - Fingerprint, distortion, registration, nearest neighbor, regression, ridge orientation map, period map.

1.INTRODUCTION

Over the last forty years there has been a rapid development in automatic fingerprint recognition technologies. Yet, there still exist challenging research problems in this field, for instance, recognizing low quality fingerprints. Fingerprint matcher is very sensitive to quality of image as seen in FVC2006 [3], where the matching accuracy of the same algorithm varies significantly for different databases due to dissimilarity in image quality. The difference between the result in accuracies of plain, rolled and latent fingerprint matching is even greater as seen in technology evaluations conducted by the NIST. Fingerprint recognition systems can be classified into two types- a positive system and a negative system. A positive recognition system is the one in which the user is cooperative and wishes to be identified. For instance physical access control systems. In a negative recognition system the user(e.g. criminals) is not cooperative and avoids identification, for instance identifying persons in watch lists. In a positive recognition system, low quality will lead to false rejection of legitimate users and will lead to inconvenience. Whereas, in a negative recognition system, the consequences of low quality will be much more serious as malicious users may intentionally reduce their fingerprint quality to avoid detection . In fact, it has been observed in many cases that the criminals have attempted to avoid identification by surgically altering or burning their fingerprints.

Hence it is of utmost importance to address the problem for negative fingerprint recognition system by detecting low quality fingerprints and improving their quality, to avoid false non-matches or false matches. Degradation in quality of fingerprint can geometric or photometric. Photometric degradation is caused by non-ideal skin conditions, dirty sensor surface, complex mage background etc. Whereas geometric degradation occurs due to skin distortion. Photometric degradation has been widely addressed along with evaluation and enhancement algorithms . But the issue of geometric degradation has yet not received sufficient attention and so we aim to attend to this problem.

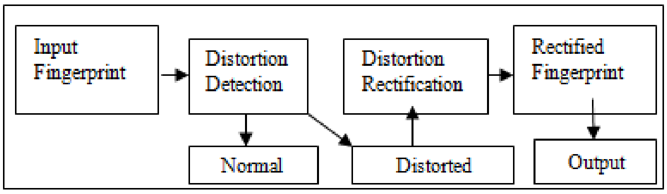

Fig -1: System Architecture

See fig.1 for the flowchart of the proposed system. Fingerprint is taken as input and distortion detection is performed using a two-class SVM classifier (registered ridge orientation map and period map are used as feature vectors).If it is found that the fingerprint is distorted, then distortion rectification is performed to transform the distorted fingerprint to a normal one. Distortion field estimation is viewed as a regression problem. Here, the input will be distorted fingerprint and the output will be corresponding distortion field. To address this, a database of various distorted fingerprints along with their corresponding distortion fields is built in the offline stage. In the online stage the nearest neighbor of input fingerprint is found in the database of distorted reference fingerprints and the corresponding distortion field is used to rectify the input fingerprint.

2. Related work

As the urgency to address the problem of distorted fingerprints rose, many researchers took an interest in addressing this problem. The methods proposed by them can be broadly classified into four categories.

2.1 DETECTING DISTORTION WITH THE HELP OF SPECIAL HARDWARE

If we detect fingerprint distortion while fingerprint acquisition , then distorted fingerprint can be rejected immediately. Many researchers have proposed this idea to detect incorrect force using specially designed hard-ware [16], [17], [18]. Bolle et al. [16] proposed to detect excessive force and torque exerted by user while acquisition using a force sensor. It was observed that that controlled fingerprint acquisition leads to improved matching efficiency [17]. Fujii [18] proposed to detect distortion by detecting deformation of a transparent film which was attached to the surface of the sensor. Dorai et al. [19] suggested to detect distortion by analyzing the motion of fingerpnint in video. However, the above methods show the following limitations: (i) Special hardware is required; (ii) Distorted fingerprints in existing database cannot be detected.

2.2 DISTORTION TOLERANT MATCHING

The most famous and easiest way to handle distortion is to make the fingerprint matcher tolerant to distortion [20], [21], [22], [23], [24], [25]. For the popularly used minutiae-based finger-print matching method, the following three types of approaches have been used to handle distortion: (i) assuming a global rigid transformation and using a tolerant box of fixed size [20] or adaptive size [21] in order to compensate distortion; (ii) explicitly modelling the spatial transformation by thin plate spline (TPS) model [22]; and (iii) enforcing constraint on distortion locally [24]. However, allowing larger distortion in matching eventually results in higher false match rate. For instance, if we increased the bounding zone around a minutia, many non-mated minutiae will \ get paired. In addition, allowing larger distortion in matching will slow down the matching speed enormously.

2.3 Distortion Rectification Based on Finger-Specific Statistics

Ross et al. [26], [27] learn the deformation pattern from a set of training images of the same finger and transform the template with the average deformation. They show this eventually leads to higher minutiae matching accuracy .But this method has the following limitations: (i)it is impossible to acquire multiple images of same fingerprint and existing fingerprint databases mostly contain only one image per finger; and (ii) even if multiple images per finger are acquired, it is not necessarily enough to cover various skin distortions.

2.4 Distortion Rectification Based on General Statistics

Senior and Bolle [28] developed an method to eliminate the distortion before matching stage. This method works on the assumption that the ridges in a fingerprint are equally spaced. So distortion is dealt with by normalizing ridge density in the complete fingerprint into a fixed value. Since they did not use any algorithm for distortion detection, they applied the distortion rectification algorithm to each and every fingerprint.In comparison to the other methods considered above, Senior and Bolle method has the following advantages: (i) no specialized hardware is required; (ii)Needs only a single fingerprint image as input.

But, ridge density is neither fixed within a finger nor fixed across fingers.Simply normalizing ridge density of all fingerprints will lead to loss of discriminating information in every fingerprint and will therefore increase impostor match scores. Furthermore, without any constraint on validation of ridge orientation map, this method will possibly generate fingerprints with fixed ridge period but abnormal orientation map. Compared to the first limitation, the second limitation is even dangerous, since it reduces genuine match scores. These limitations were not discovered in [28] since the algorithm was tested only on a relatively small database which consisted of six fingers and finger rotation was not taken into consideration .We try to implement the above method with its advantages and try to overcome the drawbacks.. Our method is based on results derived from real distorted fingerprints, rather than on the infeasible assumption of uniform ridge period map made in [28]. Our method also handles distortion due to rotation, In fact, our proposed method is able to deal with multiple types of distortion as long as such distortion type exists in our training set. Also, extensive experiments have been conducted by us to validate the proposed method.

3. FINGERPRINT DISTORTION DETECTION

Detection of distorted fingerprint is viewed as a two-class classification problem. The registered ridge orientation map and period map are used as a feature vector, which is then classified by a SVM classifier into distorted and normal fingerprints. The distortion detection flowchart is shown in Fig. 2.

3.1 Fingerprint Registration

To extract a meaningful vector, we register the fingerprints in a fixed coordinate system.. For this, we use a multi-reference based fingerprint registration approach. Reference fingerprints are prepared in the offline phase and registered in online phase. A reference fingerprint is registered based on the center of its finger and corresponding direction. For those fingerprints whose core points can be accurately detected by a Poincare index based method [31], the point which is the upper core point is used as the finger center. For arch fingerprints and those fingerprints whose upper core points cannot be detected correctly, we will manually approx. and fix the center point. Finger direction is defined to be vertical to finger joint and will be manually marked for all fingerprints. Since the reference fingerprints were registered in

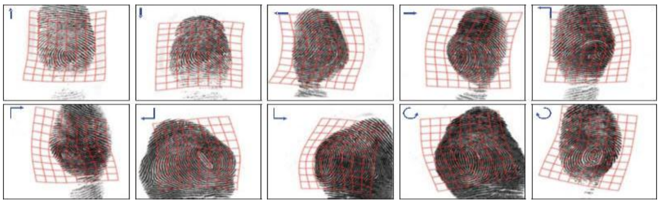

Fig 2- Examples of 10 distortion types in Tsinghua DF database

the offline stage, manual working is acceptable. Fig. 3 shows the finger center and direction for two reference fingerprints.

3.2 Online Fingerprint Registration

Input fingerprint is registered in the online the stage by extracting the features like orientation map and period map. The online registration mainly depends on upper core point of the input fingerprint. Therefore there is a possibility of two cases such when the upper core point is detected and other when the upper core point is not detected.

If we don't get the upper core point , then whole finger print is taken into consideration so as to find the pose information. If we get the upper core point , then we align the upper core point to the center point of reference fingerprints. After detecting the upper core point , finally we register the two important features of fingerprint to the fixed coordinate system by using the obtained pose information.

3.3 Feature Vector Extraction

We have extracted a feature vector by sampling registered ridge orientation map and period map. The sampling grid is as elaborated in Fig. 3, where finger center is also mentioned. Note that the two sampling grids are distinct. The sampling grid of period map covers the whole fingerprint, while the sampling grid of ridge orientation map covers only the upper part of the finger-print. This is due to the reason that the orientation maps below

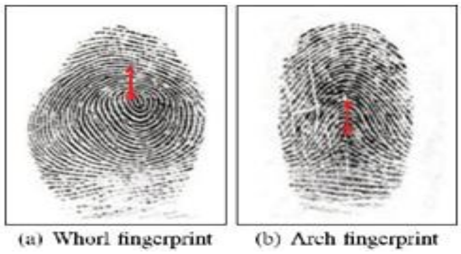

Fig 3- The centre (indicated by red circle) and direction (indicated by red arrows) of two fingerprints

Fingers center are very diverse and variable even within normal fingerprints. So they are not good features for distinguish and classification distorted fingerprints from normal fingerprints.

3.4 Distorted Fingerprint Rectification

A distorted fingerprint can be considered being generated by applying an unknown distortion field (force) **d** to the normal fingerprint, which is also not known. If we are able to approximately estimate the distortion field **d** from the given distorted fingerprint, we can easily rectify it into the normal fingerprint by applying the inverse of **d.** So we need to solve a regression problem, which is quite difficult and complex because of the high dimensionality of the distortion field (even if we use a block-wise distortion field). In this paper, we use a nearest neighbor regression approach is used for this task. The proposed distorted fingerprint rectification algorithm consists of two stages, namely an offline stage and an online stage. In the offline stage, a database of distorted reference fingerprints is created by conversion several normal reference fingerprints with various distortion fields sampled from the model of distortion fields. In the online stage, given a distorted input fingerprint (which is detected by the algorithm described in Section 3), we will retrieve its nearest neighbor in the distorted reference fingerprint database and then use the inverse of the corresponding distortion field to rectify the distorted input fingerprint.

3.5 Distortion Field Estimation by Nearest Neighbor Search

Distortion field estimation is equivalent to finding the nearest neighbor among all distorted reference fingerprints. The similarity is measured based on level 1 features of fingerprint, which are the ridge orientation map and period map. We conjecture that distortion detection and rectification of human experts also relies on these features instead of minutiae. The similarity computation method is different depending on whether the upper core point can be detected in the input fingerprint.

4 Conclusion

False non-match rates of fingerprint matchers are high in the case of highly distorted fingerprints. This generates a security issue in automatic fingerprint recognition systems which can benefit criminals and terrorists. For this purpose, it is necessary to develop a fingerprint distortion detection and rectification algorithms to fill the hole.

This paper describes a new distorted fingerprint detection and rectification algorithm. For distortion detection, the registered ridge orientation map and period map of a fingerprint are used as the feature vector and a SVM classifier is trained to classify the input fingerprint as distorted or normal. For distortion rectification (or equivalently distortion field estimation), a nearest neighbor regression approach is used to predict the distortion field from the input distorted fingerprint and then the inverse of the distortion field is used to transform the distorted fingerprint into a normal one..

A major limitation of the current approach is efficiency. Both detection and rectification steps can be significantly speeded up if a robust and accurate fingerprint registration algorithm can be developed. Another limitation is that the current approach does not support rolled fingerprints. It is difficult to collect many rolled fingerprints with various distortion types and meanwhile obtain accurate distortion fields for learning statistical distortion model. It is our ongoing work to address the above limitations.

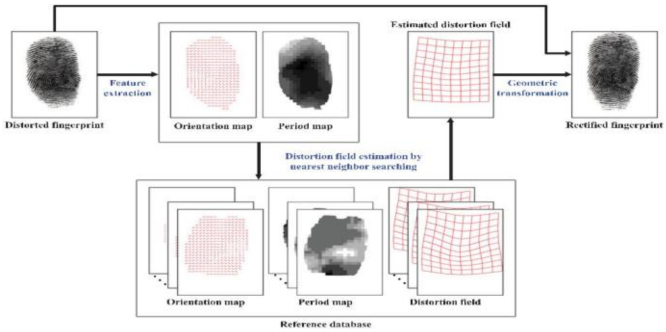

Fig.4 Distortion rectification flowchart

5 Results:

Verifinger was used for matching the fingerprints. Latent matching accuracy is reported with the help of CMC (Cumulative Match Characteristics) as shown in Fig.5. Large sets of fingerprints were used to make experiments more realistic. As Ridge Orientation Map and Period Map extracted from the original image were not reliable ,we used the features extracted from the enhanced fingerprint to rectify the distorted fingerprint.

Recognition rate improved due to the proposed algorithm. We used the database such as FVC2004 DB1, Tsinghai Distorted Fingerprint Database and NISTSD27 Latent Fingerprint Database to categories the cause of error. When a distorted fingerprint is matched with a normal fingerprint, the normal fingerprint is set as a false positive and the cause is set as false positive; otherwise the distorted fingerprint is rectified and the cause is set as low quality image and/or small finger area .The result of the statically rectification error proposed on the given database is shown below in the TABLE 1.

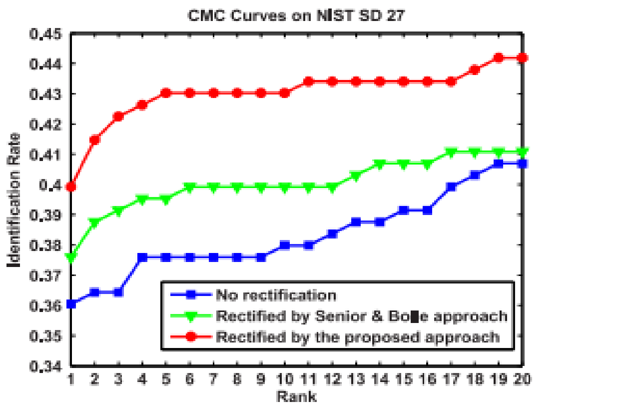

Fig.5 The CMC curves of three matching experiments on NIST SD27

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