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FINGERPRINT VERIFICATION USING GABOR FILTER BANK

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ABSTRACT

Biometrics deals with identification of individuals based on their biological or behavioral characteristics. The use of fingerprints, for identification has been employed in law enforcement for about a century. An application of fingerprint is for personal authentication, for instance to access a computer, A bank-machine, cars or home.

There are two major shortcomings of the traditional approaches to fingerprint representation. The widely used minutiae-based representation does not utilize a significant component of the rich discriminatory information available in the fingerprints. Local ridge structures cannot be completely characterized by minutiae. Further, minutiae-based matching has difficulty in quickly matching two fingerprint images containing different number of unregistered minutiae points. The proposed filter-based algorithm uses a bank of Gabor filters to capture both local and global details in a fingerprint as a compact fixed length Finger Code. We are able to achieve a verification accuracy which is only marginally inferior to the best results of minutiae-based algorithms. Our system performs better than a state-of-the-art minutiae-based system when the performance requirement of the application system does not demand a very low false acceptance rate. Finally, we show that the matching performance can be improved by combining the decisions of the matchers based on complementary

2.INTRODUCTION

The use of fingerprints as a biometric is both the oldest mode of computer-aided, personal identification and the most prevalent in use today. However, this widespread use of fingerprints has been and still is largely for law enforcement applications. This chapter contains an overview of fingerprint verification methods and related issues.

Feature Types

The lines that flow in various patterns across fingerprints are called ridges and the spaces between ridges are valleys. It is these ridges that are compared between one fingerprint and another when matching. Fingerprints are commonly matched by one (or both) of two approaches. The more microscopic of the approaches is called minutia matching. The two minutia types that are shown in Figure 1. A bifurcation is a feature where a ridge splits from a single path to two paths at a Y-junction. For matching purposes, a minutia is attributed with features. These are type, location (x, y), and direction (and some approaches use additional features).

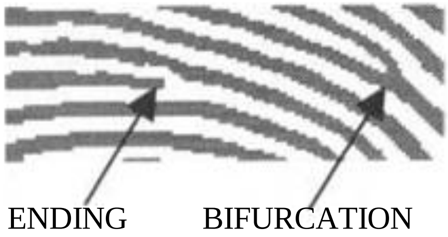

Fig. 1 Fingerprint minutiae: ending and bifurcation.

The more macroscopic approach to matching is called global pattern matching or simply pattern matching. In this approach, the flow of ridges is compared at all locations between a pair of fingerprint images. The ridge flow constitutes a global pattern of the fingerprint. Three fingerprint patterns are shown in Figure 2 (Different classification schemes can use up to ten or so pattern classes, but these three are the basic patterns.)Two other features are sometimes used for matching: core and delta. (Figure2.)The core can be thought of as the center of the fingerprint pattern. The delta is a singular point from which three patterns deviate. The core and delta locations can be used as landmark locations by which to orient two fingerprints for subsequent matching - though these features are not present on all fingerprints. There may be other features of the fingerprint that are used in matching. For instance, pores can be resolved by some fingerprint sensors and there is a body of work (mainly research at this time) to use the position of the pores for matching in the same manner that the minutiae are used. Size of the fingerprint, and average ridge and valley widths can be used for matching; however these are changeable over time. The positions of scars and creases can also be used, but are usually not used because they can be temporary or artificially introduced.

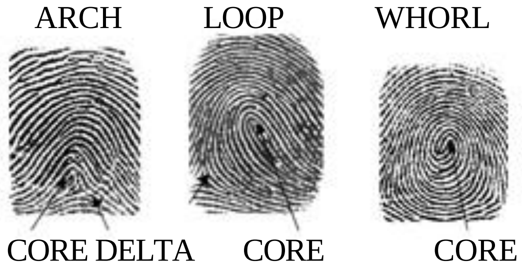

Fig. 2 Fingerprint patterns: arch, loop, and whorl.

3.IMAGE ENHANCEMENT

A fingerprint image is one of the noisiest of image types. This is due predominantly to the fact that fingers are our direct form of contact for most of the manual tasks we perform: finger tips become dirty, cut, scarred, creased, dry, wet, worn, etc. The image enhancement step is designed to reduce this noise and to enhance the definition of ridges against valleys. Two image processing operations designed for these purposes are the adaptive, matched filter and adaptive thresholding. The stages of image enhancement, feature detection, and matching are illustrated in Figure 3 there is a useful side to fingerprint characteristics as well. That is the “redundancy” of parallel ridges. Even though there may be discontinuities in particular ridges, one can always look at a small, local area of ridges and determine their flow. We can use this „„„redundancy of information” to design an adaptive, matched filter. This filter is applied to every pixel in the image (spatial convolution is the technical term for this operation). Based on the local orientation of the ridges around each pixel, the matched filter is applied to enhance ridges oriented in the same direction as those in the same locality, and decrease anything oriented differently. The latter includes noise that may be joining adjacent ridges, thus flowing perpendicular to the local flow. These incorrect “bridges” can be eliminated by use of the matched

Filter. Figure 3(b) shows an orientation map where line sectors represent the orientation of ridges in each locality. Thus, the filter is adaptive because it orients itself to local ridge flow. It is matched because it should enhance - or match - the ridges and not the noise. After the image is enhanced and noise reduced, we are ready to extract the ridges. Though the ridges have gradations of intensity in the original grayscale image, their true information is simply binary: ridges against background. Simplifying the image to this binary representation facilitates subsequent processing. The binarization operation takes as input a grayscale image and returns a binary image as output. The image is reduced in intensity levels from the original 256 (8-bit pixels) to 2 (1-bit pixels). The difficulty in performing binarization is that all the fingerprint images do not have the same contrast characteristics, so a single intensity threshold cannot be chosen. Furthermore, contrast may vary within a single image, for instance if the finger is pressed more firmly at the center. Therefore, a common image processing tool is used, called locally adaptive thresholding. This operation determines thresholds adaptively to the local image intensities. The binarization result is shown in Figure 3(c). The final image processing operation usually performed prior to minutia detection is thinning. Thinning reduces the widths of the ridges down to a single pixel. See Figure 3(d). It will be seen in the next section how these single-pixel width ridges facilitate the job of detecting endings and bifurcations. A good thinning method will reduce the ridges to single-pixel width while retaining connectivity and minimizing the number of artifacts introduced due to this processing. These artifacts are comprised primarily of spurs, which are erroneous bifurcations with one very short branch. These artifacts are removed by recognizing the differences between legitimate and erroneous minutiae in the feature extraction stage described below.

Image enhancement is a relatively time-consuming process. A 500x500-pixel fingerprint image has 250,000 pixels; several multiplications and other operations are applied at each pixel. Both matched filtering and thinning contribute largely to this time expenditure. Consequently, many fingerprint systems are designed to conserve operations at this stage to reach a match result more quickly. This is not a good tradeoff. The results of all subsequent operations depend on the quality of the image as captured by the sensor and as processed at this stage.

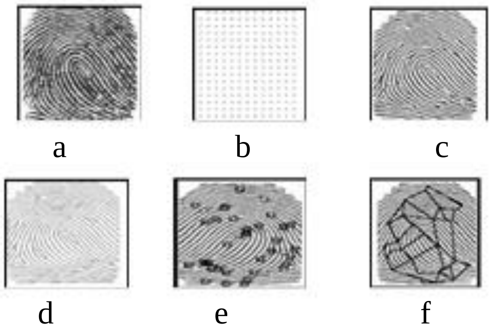

Fig. 3 Sequence of fingerprint processing steps: a) original, b) orientation, c) binarized, d) thinned, e) minutiae, f) minutia graph.

4.FILTER BANK THEORY:

With the advent of electronic banking, e-commerce, and smart cards and an increased emphasis on the privacy and security of information stored in various databases, automatic personal identification has become a very important topic. Accurate automatic personal identification is now needed in a wide range of civilian applications involving the use of passports, cellular telephones, automatic teller machines, and driver licenses. Traditional knowledge-based [password or personal identification number (PIN)] and token-based (passport, driver license, and ID card) identifications are prone to fraud because PIN‟s may be forgotten or guessed by an imposter and the tokens may be lost or stolen. As an example, MasterCard credit card fraud alone now amounts to more than 450 million U.S.

Fig. 4 Ridges and automatically detected minutiae points in a Fingerprint image. The core is marked with a X.

Biometrics, which refers to identifying an individual based on his or her physiological or behavioral characteristics, has the capability to reliably distinguish between an authorized person and an imposter. A biometric system can be operated in two modes: 1) verification mode and 2) identification mode. A biometric system operating in the verification mode either accepts or rejects a user‟s claimed identity while a biometric system operating in the identification mode establishes the identity of the user without claimed identity information. In this work, we have focused only on a biometric system operating in the verification mode

Among all the biometrics (e.g., face, fingerprints, hand geometry, iris, retina, signature, voice print, facial thermo gram, hand vein, gait, ear, odor, keystroke dynamics, etc. [2]), fingerprint- based identification is one of the most mature and proven technique. A fingerprint is the pattern of ridges and valleys on the surface of the finger [3]. The uniqueness of a fingerprint can be determined by the overall pattern of ridges and valleys as well as the local ridge anomalies [a ridge bifurcation or a ridge ending, called minutiae points (see Fig. 1)]. Although the fingerprints possess the discriminatory information, designing a reliable automatic fingerprint matching algorithm is very challenging (see Fig. 5). As fingerprint sensors are becoming smaller and cheaper [1], automatic identification based on fingerprints is becoming an attractive alternative/complement to the traditional methods of identification. The critical factor in the widespread use of fingerprints is in satisfying the performance (e.g., matching speed and accuracy) requirements of the emerging civilian identification applications. Some of these applications (e.g., fingerprint-based smartcards) will also benefit from a compact representation of a fingerprint.

Fig. 5. Difficulty in fingerprint matching. (a) and (b) have the same global configuration but are images of two different fingers.

For typical fingerprint images scanned at 500 dpi, there is a little variation in the spatial frequencies (inter-ridge distances) among different fingerprints. This implies that there is an optimal scale (spatial frequency) for analyzing the fingerprint texture. Every point in a fingerprint image is associated with a dominant local orientation and a local measure of coherence of the flow pattern. A symbolic description of a fingerprint image can be derived by computing the angle and coherence at each point in the image. Fingerprints can be identified by using quantitative measures associated with the flow pattern (oriented texture) as features. It is desirable to explore representation schemes which combine global and local information in a fingerprint. We present a new representation for the fingerprints which yields a relatively short, fixed length code, called Finger Code suitable for matching as well as storage on a smartcard. The matching reduces to finding the Euclidean distance between these Finger-Codes and hence the matching is very fast and the representation is amenable to indexing. We utilize both the global flow of ridge and valley structures and the local ridge characteristics to generate a short fixed length code for the fingerprints while maintaining a high recognition accuracy. scheme of feature extraction tessellates the region of interest of the given fingerprint image with respect to a reference point (Fig. 6). A feature vector is composed of an ordered enumeration of the features extracted from the (local) information contained in each sub image (sector) specified by the tessellation. Thus, the feature elements capture the local information and the ordered enumeration of the tessellation captures the invariant global relationships among the local patterns. The local discriminatory information in each sector needs to be decomposed into separate components. Gabor filter banks are a well-known technique to capture useful information in specific band pass channels as well as to decompose this information into biorthogonal components in terms of spatial frequencies. A feature vector, which we call Finger Code, is the collection of all the features (for every sector) in each filtered image. These features capture both the global pattern of ridges and valleys and the local characteristics. Matching is based on the Euclidean distance between the Finger Codes.

5.FILTER-BASEDFEATURE EXTRACTION

It is desirable to obtain representations for fingerprints which are scale, translation, and rotation invariant. Scale invariance is not a significant problem since most fingerprint images could be scaled as per the dpi specification of the sensors. The rotation and translation invariance could be accomplished by establishing a reference frame based on the intrinsic fingerprint characteristics which are rotation and translation invariant. It is also possible to establish many frames of reference based upon several landmark structures in a fingerprint to obtain multiple representations. At the expense of additional processing and storage cost, the multiple representations offer robust matching performance when extraction algorithm fails to detect one or more frames of reference. In the proposed feature extraction scheme, translation is handled by a single reference point location during the feature extraction stage. The present implementation of feature extraction assumes that the fingerprints are vertically oriented. In reality, the fingerprints in our database are not exactly vertically oriented; the fingerprints may be oriented up to away from the assumed vertical orientation. This image rotation is partially handled by a cyclic rotation of the feature values in the Finger Code in the matching stage; in future implementations, the image rotation will be correctly handled by automatically determining the fingerprint orientation from the image data. The current scheme of feature extraction tessellates the region of interest in the given fingerprint image with respect to the point of reference.

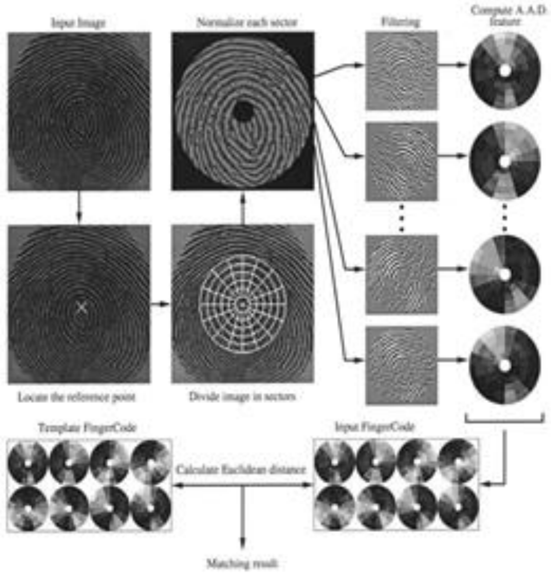

Fig .6 System diagram of our fingerprint authentication system.

The main steps in our feature extraction algorithm are

1) Determine a reference point for the fingerprint image;
2) construct the region of interest around the reference point;
3) Filter the region of interest in eight different directions using a bank of Gabor filters.

4) Compute the average absolute deviation from the mean (AAD) of gray values in individual Sectors in filtered images to define the feature vector or the Finger Code.
5) Finding Euclidean distance between the corresponding finger codes;
6) Matching is based on the Euclidean distance between the Finger Codes.

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