



PERSONAL IDENTIFICATION BASED ON ORDINAL MEASURES OF IRIS PATTERNS

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ABSTRACT

This paper introduces the rich texture information of human iris which is useful for identity authentication. A key and still open issue in iris recognition is to represent such textual information using a compact set of features. Here we propose using ordinal measures for iris feature representation with the objective of characterizing qualitative relationships between iris regions rather than precise measurements of iris image structures. Such a representation may lose some image-specific information, but it achieves a good trade-off between distinctiveness and robustness. We show that ordinal measures are intrinsic features of iris patterns and largely invariant to illumination changes. Moreover, compactness and low computational complexity of ordinal measures enable highly efficient iris recognition. Ordinal measures are a general concept useful for image analysis and many variants can be derived for ordinal feature extraction. In this paper, we develop multilobe differential filters to compute ordinal measures with flexible intralobe and interlobe parameters such as location, scale, orientation, and distance. Experimental results on three public iris image databases demonstrate the effectiveness of the proposed ordinal feature models.

Keywords :- Biometrics, iris recognition, multilobe differential filter, ordinal measures, feature representation.

I. INTRODUCTION

Reliable automatic recognition of persons has attractive goal. Since all pattern recognition has problems, it is necessary to have the relation between interclass and intra-class variability. Consider, in face recognition system, difficulties arise when the fact that the face is a changeable social organ displaying a variety of expressions, as well as being an active 3D object with viewing angle, image varies, pose, illumination, accoutrements, and age. It has shown that for facial images though they are taken at least one year long, even the best current algorithms have error rates of 43% (Phillips et al. 2000) to 50% (Pentland et al. 2000). Against this intra-class variability, inter-class variability is limited because different faces may possess the same basic set of features, in the same canonical geometry.

In IRIS recognition, as an extremely reliable method for identity authentication, plays a more and more important role in many critical applications, such as, national ID card, welfare distribution, access control, mission children identification, border crossing ,etc. The uniqueness of iris pattern come from richness of texture details in iris images, such as freckles, coronas, furrows, crypts, etc. It is commonly believed that it is quite impossible to find two persons with identical iris patterns, even they are twins. The irregularly shaped and randomly distributed microstructures of iris patterns make the human iris the most informative biometric traits.

For these reasons, iris pattern becomes interesting alternative approach to reliable visible recognition of persons when imaging can be done at distances of about less than a meter. Although small (11 mm) and sometime

problematic to image, the iris has a great mathematical advantage of pattern variability among different person is enormous. In addition to that, as an internal organ of the eye, the iris is well protected from the environment and is certainly stable over time. As the planer object its image is relatively insensitive to angle of illumination and changes in viewing angle cause only affine transformation; even the non-affine pattern distortion caused by pupillary dilation is readily reversible. Finally, the ease of localizing eyes in faces, and the distinctive annular shape of the iris, facilitates reliable as well as isolation of this feature and the creation of the size-invariant representation.

Human iris identification process is basically divided into four steps,

1. *Localization*- The outer and the inner boundaries of the iris are localized and calculated.
2. *Normalization*- Iris of different people may be captured in different size. For the same person also size may vary due to the variation in illumination and other factors.
3. *Feature extraction*- Iris provides plenteous texture information. A feature vector is formed from the various representation of the iris images which consist of ordered sequence of features.
4. *Matching*- The feature vectors are classified with the help of different thresholding techniques like hamming distance, weight vector and winner selection, dissimilarity function, etc.

In this paper, an attempt to answer some of the questions, we introduce ordinal measures for iris image representation. Ordinal measure focus on encoding qualitative information of visual signal rather than its quantitative values. In iris recognition, the absolute intensity information associated with an iris pattern can vary because it may change under different illumination settings. However, ordinal measures are known for stability among neighboring image pixels or region exhibit some with some changes and reflect the intrinsic properties of iris. The microstructures of iris patterns, exhibit sharp intensity variations in iris images, which has numerous high contrast and stable ordinal relationship between iris regions. Therefore ordinal measures are expected to have the capability of representing the robust and distinctive features of iris patterns.

II. ORDINAL MEASURES AND THEIR PROPERTIES FOR IRIS IMAGE ANALYSIS

2.1 A Brief Introduction to Ordinal Measures

Stevens suggested four levels of measurements from coarse to fine: nominal, ordinal, interval, and ratio measures. Ordinal measures is a simple and straightforward concept that we often use. For example, we can easily rank or heights or weights of two persons, but it is hard to tell their precise differences. This kind of qualitative measurement, that is related to the relative ordering of several quantities, is defined as ordinal measures (OMs).

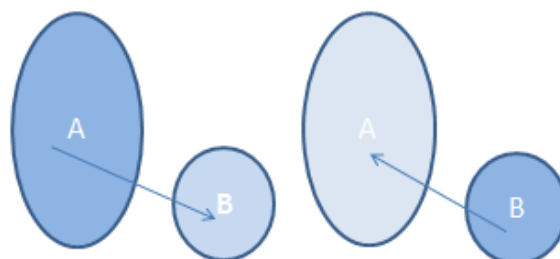


Fig 1. Ordinal measure of relationship between two regions. An arrow points from the darker region to the brighter one.



A simple illustration of ordinal measures is shown in fig. 2, where the symbol “<” or “>” denotes the inequality between the average intensities of two image regions. The inequality represents an ordinal relationship between two regions and this yields a symbolic representation of the relations. In digital encoding of the ordinal relationship, only a single bit is enough, e.g., “0” for “ $A < B$,” and “1” for “ $A > B$ ” and the equality case (a low probability event) can be assigned to either.

The advantages of ordinal measures in the field of visual representation have already been verified by some pioneering work in the literature. Based on the fact that several ordinal measures on facial images, such as eye-forehead and mouth-cheek, are invariant to individuals and imaging conditions, Sinha developed a ratio template for face detection, which can be automatically learned from examples [04], [09]. Sinha was the first to introduce ordinal measures to computer-based vision systems [11]. Combining qualitative spatial and photometric relationships together, Lipson et al. applied ordinal measures to image database retrieval.

2.2 Desirable properties of Ordinal Measures

The ordinal measures is very much desirable for accurate and robust iris recognition. This is briefly discussed in the following.

2.2.1 Robustness of Ordinal Measures

Formation of an iris image is jointly determined by both extrinsic factors (illumination and distance, position, rotation, etc.) and intrinsic factors (anatomical characteristics). Intrinsic factors are identity-related and stable for personal recognitions, but extrinsic factors are independent of identity and variable under various imaging conditions. Iris image preprocessing method can normalize the factors such as translation, scale, and rotation, which are external. Ordinal measures indicate intrinsic iris features and are largely invariant to illumination changes.

2.2.2 Uniqueness of Ordinal Measures

Iris pattern is one of a random texture characterized by many interlacing minute structures. The micro anatomical structure in the iris surface may exhibits different reflectance properties in infrared light, leading to sharp intensity variations across iris image regions. The noise-like parameters may disturb the accuracy of traditional-segmentation-based computer vision algorithms. On the other hand, the numerous image region pairs with significant intensity difference provide abundant high-quality building blocks for ordinal template construction. We may imagine that the richness of the uncorrelated ordinal measures is critical to the uniqueness of iris pattern. For an arbitrary pattern, its ordinal measure has equal probability to be “1” or “0.” It is easy to find hundreds of independent ordinal measures in a typical iris image [1], [2], so a well-developed ordinal feature template of iris image should have at least hundreds of degrees-of-freedom for personal identification. Although the discriminating power of a single-bit ordinal measure is limited the composite iris representation constituted by thousands of robust ordinal measures is powerful for large-scale personal identification.

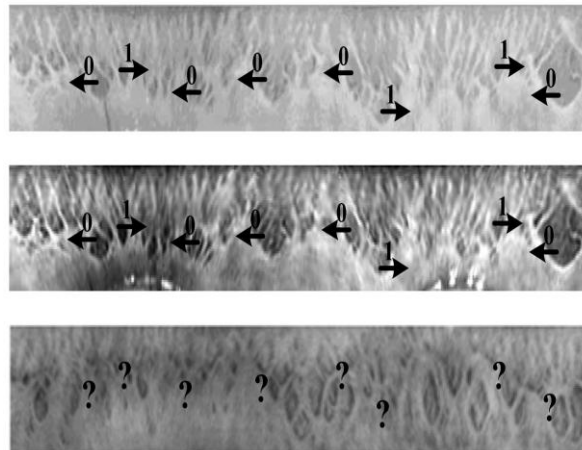


Fig 3. Comparison of intraclass and interclass ordinal measures in normalized iris images.

2.2.3 Efficiency of Ordinal Measures

A well developed-iris feature representation should reduce the computational complexity of feature extraction and feature matching to a minimum, which is beneficial to large-scale deployment and embedded applications of iris recognition. Ordinal feature extraction typically involves only additions and subtractions (e.g., the ordinal measure in Fig. 2 can be computed by sum (region A)-sum (region B)). This makes ordinal measures well suited for iris recognition on many weak computational platforms such as mobile phones and PDAs as they are not good at multi-operations and divisions. The dissimilarity between two ordinal templates can be measured by bitwise XOR operator, which can be computed on-the-fly and can be easily implemented by hardware.

III. ORDINAL FEATURE EXTRACTION FOR IRIS RECOGNITION

In the preceding sections, we have discussed the basic concept of ordinal measures and their desirable properties in context of iris recognition. We now turn our attention to the issue of how to extract ordinal iris features.

Ordinal feature extraction of iris images is not a challenging issue due to the theoretical simplicity of ordinal measures. For example, an ordinal measure can be easily obtained by qualitative comparing the features of two groups of image regions (see Fig. 5 for an example). However, due to attention should be paid to the selection of a number of intra and interregion parameters such as shape of regions, orientation of regions, location of regions, regional feature type (average intensity, wavelet coefficient, etc.), interregion distance, spatial configuration of regions, etc. These parameters leads to great flexibility in designing a particular scheme for ordinal iris feature extraction. In this sense, ordinal measures make it possible for us to develop a general framework for iris feature extraction. Specific feature extraction can be derived from variation of these parameters.

In this paper, we propose multilobe differential filters (MLDFs) for ordinal iris feature extraction, aiming to model the flexibility of ordinal measures. Mathematically, the MLDFs are given as follows when Gaussian kernel is employed as the basic lobe:

Each ordinal measures may have its unique visual meanings. For example, as Fig. 6 shows, a group of two lobe orientational measures may denote point, line, edge, corner, ridge, slope, etc.

The procedure of iris feature extraction using MLDF is as follows: An MLDF operator slides across the whole normalized iris image and each ordinal comparison is encoded as one bit, i.e., 1 or 0 according to the sign of the

filtering result. All the binary iris codes constitute a composite feature of the input iris image, namely, ordinal code (OC). The dissimilarity between two iris images is determined by the Hamming distance of their features. In order to cope with the possible rotation difference between the two iris images, the input ordinal code is circularly rotated at different starting angles to match the template ordinal code. And the minimum Hamming distance of all matching result is the measure describing the dissimilarity between the two iris images. Because iris localization and normalization have complimented the position and scale differences between two iris images, the whole procedure of iris matching is insensitive to position, scale, and rotation changes.

In summary, iris feature based on ordinal comparisons represent iris image contents at three level of scales: each iris feature element (ordinal code) describe the ordinal information of an image patch covered by the MLDF which is localized by the central pixel of the image patch; each ordinal measure is jointly determined by weighted intensities of several regions; and finally, all ordinal measures are concatenated to build a global description of the iris image.

IV. EXTRACTING IRIS RECOGNITION ALGORITHMS IN THE CONTEXT OF ORDINAL MEASURES

Based on ordinal measures, we can provide a general framework for iris feature representation and extraction. Specific iris coding schemes can be obtained under the guidance of this framework by changing parameter configurations. Furthermore, with the above OM representation model in place, we show in the following that iris image features of a number of best-performing iris recognition methods may be interpreted as special case of this model.

Similarly, the Harr wavelet [9], quadratic spline wavelet [6], [10], and the derivative of Gaussian filter may also be seen as typical ordinal filters (Fig. 5). The encoding methods of [9], [10], are based on the sign representation of ordinal filtering results. Ma et al. [6] used the wavelet transform results as the measurement for ordinal comparisons and magnitude threshold was used to suppress the insignificant ordinal measures. Monro et al. proposed to compare the power spectrum of two iris image patches for ordinal encoding [10]. These iris recognition methods all perform well in large scale testing.

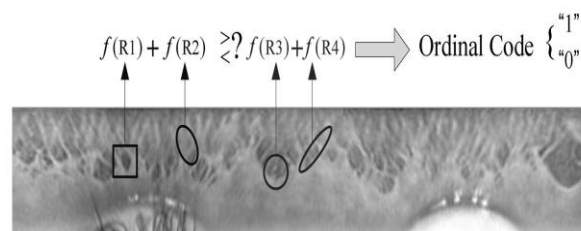


Fig 4. Computing ordinal measures of iris image.

V. EXPERIMENTAL RESULTS:

Extensive experiment have been conducted to evaluate the performance of the proposed ordinal measures for iris recognition.

These databases represent the most challenging data set for iris recognition currently available in the public domain. The Gabor phase encoding method (iris code) [1], [2], which is the most successful iris recognition algorithm in commercial application, and local sharp variation method (shape code) [6], which achieved high

performance both accuracy and speed simultaneously, are implemented by ourselves as the benchmark algorithms in this paper.

Before iris image feature extraction using different encoding algorithms, the original iris image must be preprocessed. It mainly includes iris localization and normalization .

Since the focus of this paper is on iris feature representation, details of iris image preprocessing are not reviewed here but may be found in the literature [1], [3], [5], [6].

5.1 Results on the CASIA Iris Image Database

CASIA Iris Image Database developed by our research group has been released to the international biometrics community for many years and has been considered as a standard database for the evaluation of iris recognition algorithms [06]. An earlier version of this database, CASIA Iris Database Ver 1.0 (CASIA V1.0), has been widely used in the literature, and it is also employed here as a

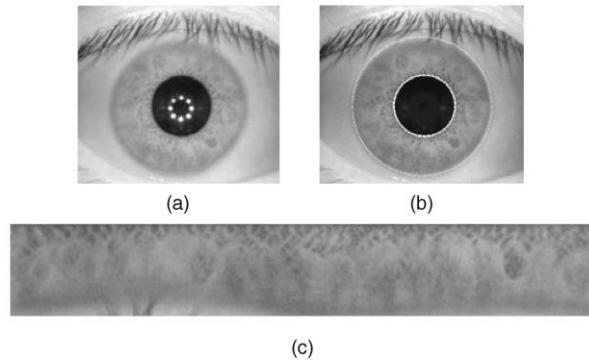


Fig 5. Illustration of iris image preprocessing (a) Origan iris image (b) Iris localization (c) Iris normalization.

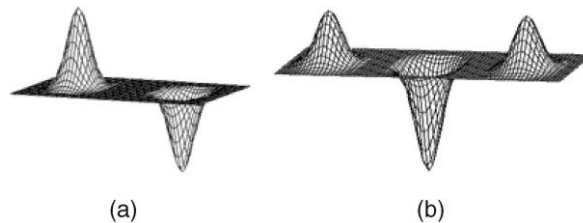


Fig 6. Two kinds of multilobe differential filters. (a) Dilobe ordinal filter (b) Trilobe ordinal filter.

benchmark to facilitate comparison between our results and others. Iris images of CASIA V1.0 were captured with a homemade iris camera. CASIA V1.0 contains 756 iris images from 108 subjects. In order to protect our IPR in the design of the iris camera (especially the NIR illumination scheme) before appropriate patents were granted, the pupil regions of all iris images in CASIA V1.0 were detected automatically and replaced with a circular region of constant intensity to mask out the specular reflections from the NIR illuminators before public release. Clearly, such processing may affect pupil detection but has basically no effects on other components of an iris recognition system such as iris feature extraction since it only uses the image data in the region between the pupil and the sclera, i.e., the ring-shaped iris region. All possible intra and interclass iris matching are performed on CASIA V1.0.

TABLE 1 Comparison of Recognition Performance on CASIA V1.0 Database

Method	EER	DI	Template (Bytes)	Time (ms)



Di-lobe OC(d=5)	5.95×10^{-5}	3.90	128	5.2
Tri-lobe OC(d=5)	1.92×10^{-2}	3.33	128	5.2
Local OC(Di- lobe d=5 plus Tri-lobe d=5)	5.65×10^{-3}	3.66	256	10.4
Non-local OC(Di-lobe d=5 plus Tri- lobe d=5)	3.70×10^{-3}	4.39	256	10.4
Iris code	6.76×10^{-3}	3.73	256	35.2
Shape code	5.01×10^{-3}	3.87	256	29.6

In addition to CASIA V1.0, the latest version of the CASIA database, CASIA-IrisV3, is also used in this paper for testing. In particular, one of CASIA-IrisV3's three subsets, namely, CASIA-IrisV3-Interval, is used for evaluation in this paper. There are totally 2,655 iris images in this subset, acquired from 396 eyes of 249 subjects. Most volunteers of CASIA database are Chinese and most images were captured in two sessions, with at least one-month interval. All possible intra- and interclass iris matchings are performed on CASIA-IrisV3-Interval and the experimental results are shown in Figs. 5 and 6 .

VI. DISCUSSIONS AND CONCLUSIONS

In this paper, a novel and general framework for iris feature representation and recognition has been presented. The framework is based on ordinal measures, a theoretically simple but practically very powerful feature model.

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