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Predictive models for multibiometric systems

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ABSTRACT

Recognizing a subject given a set of biometrics is a fundamental pattern recognition problem. This paper builds novel statistical models for multibiometric systems using geometric and multinomial distributions. These models are generic as they are only based on the similarity scores produced by a recognition system. They predict the bounds on the range of indices within which a test subject is likely to be present in a sorted set of similarity scores. These bounds are then used in the multibiometric recognition system to predict a smaller subset of subjects from the database as probable candidates for a given test subject. Experimental results show that the proposed models enhance the recognition rate beyond the underlying matching algorithms for multiple face views, fingerprints, palm prints, irises and their combinations.

1. Introduction

Biometric systems are increasingly being deployed for identification, access control and surveillance [1]. Traditional deployments were mainly unimodal biometric systems which used a single sample from a single biometric modality. Performance of such systems suffered from noisy data, intra-class variations, interclass similarities, non-universality and spoofing [2]. Some of these problems are addressed by using multibiometrics [2,3].

The term multibiometrics is used to denote three distinct classes of biometric systems: *multisample*, *multiview* and *multimodal*. In multisample biometrics, multiple samples are obtained from the same modality without any change in parameters. Examples are multiple images of the frontal view of the face, fingerprints of the same finger, iris images of the same eye etc. It has been shown that multisample biometrics can provide better recognition results compared to single sample results [4,5].

In multiview biometrics, samples are taken from the same biometric modality but under different conditions such as different face poses, different fingers, and different irises. Face recognition using multiple poses of face images, person identification using tenprint fingerprints, video based face recognition of walking persons etc. constitute examples of multiview biometric systems.

In multimodal biometrics, samples from different biometric modalities such as face, fingerprint, palmprint, iris, etc. are used. Multimodal biometrics provide better and robust authentication and security [3] compared to unimodal biometric systems. A very visible use of multimodal biometrics is the US-VISIT program where the ten fingerprints, face and iris images of all international visitors are collected [6].

Even with multibiometrics, the matching subject returned by the recognition system may not be the true match [7]. Thus, a biometric recognition system generally provides a set of ranked matching subjects instead of just one matching subject. The performance of a biometric recognition system is typically characterized by the Cumulative Match Characteristic (CMC) Curve which provides a plot of the identification rate against rank k, where k is the number of top candidates [7].

This paper describes novel and generic statistical predictive models, which can predict the matching subjects in a multiview/multimodal biometric environment, depending on whether the *view details* of the test subject are known or not. By view details we mean the specific face pose (frontal, profile, etc.), the specific finger from which the fingerprint is taken, etc. The first model is called the Multinomial Model (MM) and is based on multinomial probability distribution. The second is called the Geometric Model (GM) and is based on geometric probability distribution. Both the approaches model the similarity scores produced when a test subject is matched against all the subjects in a database, and therefore, they are generic in nature. They can be applied to any biometric, provided a matching algorithm for that biometric is available. The models proposed in the paper model the score distributions and draw inferences regarding retrieval rankings based on those models. They do not explicitly model the recognition systems. The term predictive is used to emphasize the application of the models as the models are used to predict the ranking of the retrievals.

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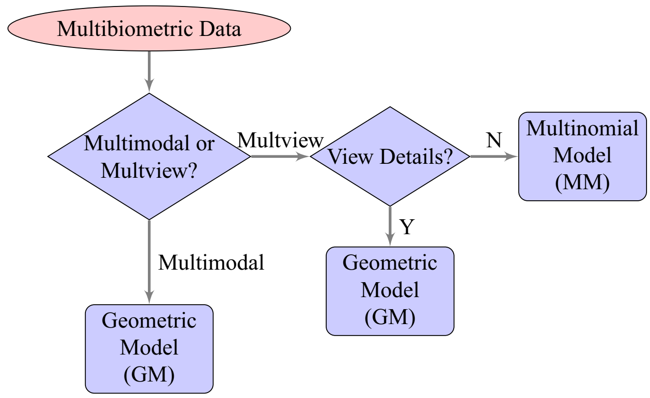

Fig. 1. Which model (GM or MM) to use for prediction?

The GM can be used in multiview systems where the view details are known. GM can also be used for predicting the matching subjects in multimodal biometric systems as the modality information of the test subjects is obviously available (e.g., it will be known if the test image is a fingerprint, palm print, etc.). The MM is suited for the multiview situations where the view details of the test subject are not known in advance. This can occur, for example, in surveillance systems where multiple views of a non-cooperative subject are matched against all the views present in a database. The flow chart in Fig. 1 shows how to choose the appropriate model based on the problem. Our prediction models are validated on a variety of publicly available databases of fingerprints, faces, palms, and irises.

When data from different biometric samples or modalities are available, an overall recognition result is typically obtained by fusing the individual results [4]. Therefore, the experimental results in this paper are compared with fusion results.

The paper is organized as follows. Section 2 describes the related work and our contributions. Section 3 describes the technical approach which begins with an overview and is followed by the detailed descriptions of both the proposed statistical models. Section 4 describes the results of our experiments on five different databases and Section 5 concludes the paper.

2. Related works and contributions

2.1. Related work

Typically, the different aspects of performance of a recognition system are predicted by modeling either the similarity scores or the feature space. A summary of the representative research in these areas is provided in this subsection.

Many researchers have used binomial probability distributions for modeling the similarity scores. Wayman [8] used them under the assumption of independence of errors, to estimate the probability that a false match never occurs. The paper derived equations for error rate. Daugman [9] described the use of binomial models for predicting whether the given distance metric belongs to the same iris or different irises. This is achieved by noting that the distance metric for similar and dissimilar pair of irises falls into two distinct binomial distributions. However it has been reported in [10] that the models proposed by [8,9] predicted exponential decrease in recognition rate when the database size increased while in reality the decrease is linear in the logarithm of the database size.

The face recognition vendor test report 2002 [10] provided another model for predicting the identification rate using the moments of the match score distribution. But the model underestimated the identification rates. The model was based on the assumption that the similarity scores are independent and identically distributed. In practice this assumption needs not to be valid. Jhonson et al. [11] presented a method to estimate recognition performance for large galleries of individuals using data from a significantly smaller gallery. This was achieved by modeling the CMC curve using binomial distribution. The same problem has been addressed in a different way by Wang and Bhanu [12] for fingerprint recognition with the additional assumption that the match and nonmatch score distributions remain the same when the gallery size is increased. Grother and Phillips [13] presented the prediction of the recognition performance of large sized biometric galleries using a binomial model under the assumption that the match score distribution and the nonmatch score distribution are independent. Dass et al. [14] predicted confidence regions based on the Receiver Operating Characteristic (ROC) curve. This was accomplished by estimating genuine and imposter distributions of similarity scores through Gaussian copula models.

In contrast to the above, Wang et al. [15] presented an approach where performance prediction was used to increase the recognition rate which is the theme of this paper as well. Even though their method is generic, the increase in the recognition rate is achieved by discarding poor quality test subjects from the testing process. The poor quality test subjects are identified using a SVM classifier. In comparison, the work presented in this paper, builds statistical models for predicting matching subjects and achieves a higher recognition rate compared to the underlying matching algorithm by using all test subjects.

The research related to performance prediction where the feature space is modeled is described below. Schmid and O'Sullivan [16] described a framework for determining the performance of physical signature authentication based on likelihood models. Vectors of features extracted from the signatures were modeled as realizations of random processes. These random processes and the resulting distributions on the measurements determined bounds on the performance, regardless of the implementation of the recognition system. Boshra and Bhanu [17] presented a different approach to predicting probability of correct recognition by modeling the uncertainty, clutter, and occlusion of the 2D feature vectors of a subject which was verified on synthetic aperture radar data. In [18], Aggrawal et al. proposed a framework for predicting the success and failure of an algorithm in a face verification scenario. This method is specific to face recognition. Pankanti et al. [19] studied individuality of fingerprints, meaning they estimated the probability that two fingerprints from two different fingers are considered to be the same. Tan and Bhanu [20] provided an improvement over [19] with a two-point model and a three-point model to estimate the error rate for the minutiae based fingerprint recognition. The approach measured minutiae's position and orientation, and the relations between different minutiae to find the probability of correspondence between fingerprints. They allowed overlap of the uncertainty area of any two minutiae.

2.2. Contributions

1. The paper develops novel and generic statistical models, which are independent of the biometrics and the matching algorithm, for predicting the matching subjects in a multi-biometric recognition system. In our preliminary work [21], we used the geometric model for predicting indexing performance.
2. The paper shows that using the proposed framework enhances the recognition rate of the underlying matching algorithm for different biometrics.
3. The proposed prediction model is validated on several publicly available databases of face, fingerprint, iris, and palmprint.