Intra-Class Threshold Generation in Multimodal Biometric Systems by Set Estimation Technique

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ABSTRACT

Biometric recognition techniques attracted the researchers for the last two decades due to their many applications in the field of security. In recent times multimodal biometrics have been found to perform better, in several aspects, over unimodal biometrics. The classical approach for recognition is based on dissimilarity measure and for the sake of proper classification one needs to put a threshold on the dissimilarity value. In this paper an intra-class threshold for multimodal biometric recognition procedure has been developed. The authors’ selection method of threshold is based on statistical set estimation technique which is applied on a minimal spanning tree and consisting of fused face and iris images. The fusion is performed here on feature level using face and iris biometrics. The proposed method, applied on several multimodal datasets, found to perform better than traditional ROC curve based threshold technique.

Keywords: Convex Combination, Equal Error Rate (EER), False Acceptance Rate (FAR), False Rejection Rate (FRR), Feature Extraction and Reduction, Feature Level Fusion, Intra-Class Threshold, Minimal Spanning Tree (MST), Multi Modal Biometrics, Set Estimation

1. INTRODUCTION

Multimodal biometrics (MMB) has gained popularity among researchers as they provide more information for processing purpose of an individual rather than a unimodal biometric system. Secured MMB systems (MMBS) should be capable of authenticating a person’s identity based on his biometric traits like faces (Bourlai, Kittler, & Messer, 2009; Geng & Jiang, 2013), fingerprints (Mehtre, 1993; Hiew, Teoh, & Yin, 2010), iris (Wildes et al., 1996) etc. In MMBS,
at least two different biometrics need to be fused. Levels of fusion (Ross & Govindarajan, September 2004) can be raw level, feature level, match score level or decision level. Fusion at feature level, though difficult and understudied (Ross & Govindarajan, March 2005), possesses more importance than the other levels, because extracted feature set from raw data holds most significant and rich information. Several evaluation protocols (P. Grother & Bone, 2003; A. K. Jain & Prabhakar, January, 2004; Blackburn, 2004), on closed test set identification, have been designed for measuring the performance of different existing algorithms. In open test identification, the challenge is to reject the imposters. Selection of proper intra-class threshold is a way of accepting genuine users or rejecting fraudulent attempts as imposters. However, selection mechanism of proper threshold is an open research area as it is hurdled by different levels of security.

In several articles (Manseld & Wayman, 2002), Equal Error Rate (EER), the point where False Acceptance Rate (FAR) and False Rejection Rate (FRR) intersects, in a Receiver Operating Characteristics (ROC) curve, had been selected as decision threshold. Martin et al. (A. Martin, 1997) proposed the use of detection error trade-off (DET) curve, a non-linear transformation of ROC curve, as a threshold selection tool. In principle, both the curves for threshold determination are useful, provided the threshold value is computed over large numbers of test images and hence is computationally expensive.

To design MMBS, ROC curve based method is not a stable solution due to the following reasons. (a) A good estimate of FAR cannot be determined as it is impossible to include even a single representative of all possible imposter instances. (b) In reality, a system can have extremely few genuine accesses and also relatively few imposter accesses because there exist infinitely many imposters in the universal set. (c) The common practice is to use a global threshold for a system rather than user specific version of ROC.

In MMB the submitted query image, Q, can be categorized to the following types. (a) Q is not a valid MMB image under consideration (P). For example, if the MMB dataset consists of face and fingerprint biometrics, the submitted Q could be a non biometric image, like an image of a car or an animal. (b) Q is mimicking the original P. For example, consider a verification system that authenticates a user by inputting his face image and fingerprints. Now, Mr. Y maliciously could place a minutely designed 3D mask of Mr. X, in front of camera and Mr. X’s false fingerprint impression on the input sensor and claim himself to be Mr. X, in order to break the security of the system. (c) Q is a valid P, but Q is an outlier of the P training set. That is, no instance of Q exists in the P training dataset. (d) At least one instance of Q does belong to P training dataset. Note that, cases (a), (b) and (c) do fall under fraudulent attempts and a robust and secured MMBS should be capable of rejecting such deceiving attempts. However, in these three cases, no sample instance of Q is present in the P datasets and hence it is virtually impossible for the system to generate a good (very low) estimate of FAR.

In the current problem, we are interested in finding threshold values for each MMB class. In this context, by MMB class of a person X, we do mean that face and iris images of X are concatenated to construct the components (images) of his class. The process of concatenation is elaborated later. An ideally constructed class of X should contain ALL possible MMB images of X, reflecting ALL possible variations. However design of such a class is not possible in reality and the class should be considered as an uncountable set. We can also assume that the class is bounded, closed and path connected (Datta & C.A.Murthy, 2012). By the term “path connected,” we mean between every two MMB image points, there exists a path joining those two points which is completely contained in the class.

After formation of the MMB class of each person of the dataset, the feature level fusion is carried out on face and iris. However, how to fuse information of two different biometrics of
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