Enhancement of Multimodal Biometric Systems Using an Improved Unconstrained Cohort Normalisation

Fawaz Alsaade

Computer Science & IT college, King Faisal University
Al-Ahsa, Saudi Arabia

Abstract :

An important factor affecting the performance of multimodal biometrics in practice is that of contamination in the individual biometric data types. This paper proposes an improved score normalisation technique to reduce the effects of such contamination in the multi-modal fusion. It is shown in this paper that by deploying such technique at the score level, the adverse effects of data degradation can be reduced considerably. The experimental investigations involve the two recognition modes of verification and open-set identification in mixed-quality data conditions. The paper presents the motivation for, and the potential advantages of, the proposed approach and details the experimental study.

Keywords: Multimodal biometrics; Score-level fusion; Unconstrained cohort normalisation; Biometric verification.

Introduction :

The problem of automatic recognition of individuals using biometrics (e.g., fingerprints, speech, and face images) has received a great deal of interest in the last few decades [Jain, *et al.*, 2004; Prabhakar, *et al.,* 2003]. Certain obvious attractions of biometrics over the conventional means of identification have made it a superior choice in a growing range of scenarios. However, whilst considerable advances have been achieved in this area, the performance of unimodal biometric techniques is still being impeded by such issues as non-universality and impersonation. Recent studies have shown that a potentially viable way of addressing such problems is the use of multiple modalities in biometric recognition [Indovina, *et al.,* 2003; Gutschoven and Verlinde, 2000]. Another major benefit offered by multimodal biometrics is that it provides the opportunity for enhancing the recognition accuracy beyond that achievable with unimodal biometrics.

Multimodality is based on the concept that the information obtained from different modalities complement each other [Indovina, *et al.*, 2003]. Consequently, an appropriate combination of such information can be more useful than using information from any of the single modalities involved alone. For this purpose, there are various data combination levels that can be considered. Examples are the feature-level, score-level and decision level [Jain, *et al.,* 2004]. It has, however, been reported that the most appropriate and effective approach to multimodal biometrics is through the fusion of data at the score level [Indovina, et al., 2003].

In general, one of the important problems associated with any multimodal as well as unimodal technique is the undesired variations in the biometric data. Such variations are reflected in the corresponding biometric scores, and thereby can adversely influence the overall effectiveness of biometric recognition. The said variations can arise due to a variety of factors such as the sensors used in capturing the biometric data and various non-ideal operating conditions such as background noise or poor lighting conditions.

This paper presents investigations for enhancing the accuracy of multimodal biometrics. This is based on improving the normalisation of the matching scores obtained for face and voice biometrics. The score-level fusion is carried out using SVM (support vector machine). The use of SVM in this work is based on earlier studies reporting it as one of the most effective methods for multimodal biometric fusion [Jain, *et al.*, 2004; Gutschoven and Verlinde, 2000]. However, because of the generality of the approach proposed in this paper, the outcomes should be applicable to other fusion methods as well.

The rest of the paper is structured as follows. Section 2 introduces the proposed approach and discusses the motivation behind its use. The experimental investigations and an analysis of the results are presented in Section 3, and the overall conclusions are given in Section 4.

The Proposed scheme

As indicated earlier, data variations are considered as one of the main problems in multimodal fusion. Such variations are reflected in the corresponding biometric scores, and can thereby adversely influence the overall effectiveness of biometric recognition. Recent studies have shown that a potentially viable way of addressing such problems is through score normalisation approaches, particularly through the use of Unconstrained Cohort Normalisation (UCN), [Alsaade, *et al.,* 2008] in fusion-based biometrics. It has been shown in [Alsaade, *et al.,* 2008] that the use of UCN helps improve the robustness of multimodal biometrics. This is because the approach provides a useful means for appropriately adjusting the individual biometric scores for a client, without any prior knowledge of the level of degradation of each biometric data type involved. Another motivation for using UCN in multimodal biometrics is that it facilitates the suppression of the individual biometric scores for impostors in relation to those for the clients.

As described in [Alsaade, *et al.,* 2008], given a test token of certain biometrics type, the normalised matching score provide through UCN can be expressed as

$$\Gamma^i = \log \rho_T^i - \frac{1}{N}\sum_{n=1}^{N} \log \rho_n^i , \qquad (1)$$

where *i* denotes the biometrics type, ρ_T^i is the score for the target model, ρ_n^i are the scores obtained for a set of competing models, and *N* is the number of competing models considered. These competing models are selected dynamically from a group of background models, based on their closeness to the test token.

As indicated from equation (1) that UCN operates on the individual biometric scores involved independently, and the accuracy of the final fused score in multimodal recognition can benefit from the enhancement achieved in all these individual scores.

Although, UCN has shown considerable improvements to the accuracy of multimodal biometrics in varied data conditions [Alsaade, *et al.,* 2008], it is believed that the accuracy of multimodal biometrics can be further enhanced if, through some means, the misclassified scores are treated in a proper way than that in the UCN. This is because the misclassified scores, in case of using UCN, are pushed away from their original class (Clients/ Impostors). In other word, misclassified client scores would be shifted towards the impostor class while the misclassified impostor scores would be pushed towards the client class. This reduces the chance of correcting the misclassified normalised scores at the fusion stage.

The proposed approach aims to solve the above mention problem. In the proposed approach, ρ_n^i (in the case of each modality) are transferred into the log domain and then averaged together to produce the normalisation term for the considered modality. The distance between such normalisation term and the logarithm of the score for the target model is then measured. Based on this distance and some preset threshold, the level of degradation is determined. As a result, replacing ρ_n^i with ρ_N^i in equation (1) for the degraded scores assures that such scores would be kept almost in their original location. This increases the chance of correcting such scores at the fusion stage.

The application of the improved UCN to multimodal biometrics fusion can be of considerable value for enhancing the reliability of the process in uncontrolled/varied operational conditions. This is because the approach provides a useful means which can potentially facilitate the separation of the scores for a given true-classified (client) from those for impostors targeting that client. On the other hand, the approach has the advantage of keeping the misclassified scores close to where there were before the normalisation process and not pushing them away from their original class. It is thought that these capabilities should significantly increase the multimodal biometric accuracy. This is because the technique operates on the individual biometric scores involved independently, and the accuracy of the final fused score in multimodal recognition can benefit from the enhancement achieved in all these individual scores.

Experimental investigations and results :

The experimental studies are concerned with the score-level fusion of face and voice biometrics in the two recognition modes of verification and open-set identification. The modelling and pattern matching approaches used with each modality is not discussed here, as these are outside the scope of this study. The investigations in each recognition mode are initially formed by using scores for clean face images together with scores for degraded utterances.

In each experiment, the individual biometric score types involved are subjected to the range equalisation process using the Min-Max normalisation [Indovina, et al., 2003; Nandakumar, 2005]. The reason of using the Min-Max technique as a replacement for Z score, in this paper, is referred to that Min-Max maps the scores in the range of [0 1] while the numerical range after Z-score normalisation is not fixed. Therefore, Min-Max can be of considerable value for enhancing the reliability of the proposed approach.

In this work, the process of score-level fusion is based on the use of linear support vector machine (SVM) [Burges, 1998; Vapnik, 1997]. The fusion process is applied to the biometric scores with and without subjecting them to the UCN process. This is to determine the level of effectiveness enhancement offered by unconstrained cohort normalisation. The competing models required for UCN are selected from within the set of registered users during the test phase. The procedures for speech feature extraction and speaker classification are as detailed in [Fortuna, 2004]. The face recognition scores are based on the approach detailed in [Zafeiriou, *et al.,* 2006]. The experimental results (i.e. verification in both modes) are accompanied by a 95% confidence interval.

3.1 Fusion under varied data conditions :

The purpose of the experiments presented in this paper is to investigate the effectiveness of the improved UCN when the biometric data types have different levels of quality. The datasets considered for the face and voice modalities in this case are extracted from the XM2VTS (clean images) [Zafeiriou, *et al.,* 2006] and from the 1-speaker detection task of the NIST Speaker Recognition Evaluation 2003 (degraded speech) databases [Fortuna, 2004]. Using these biometric datasets, a total of 140 chimerical identities are formed. These consist of 70 clients, 25 development impostors and 45 test impostors. The development data comprises 70 and 6580 (i.e. 70×{25+[70-1]}) score tokens from the same-users and impostors (including cross-users) respectively. The corresponding score tokens used in the testing phase are 70 and 7980 (i.e. 70×{45+[70-1]}) respectively. The verification results are presented as equal error rates (EERs) with a 95% confidence interval in Table 1.

Table (1)

Performance of conventional/ improved UCN in biometric verification based on mixed-quality data.

Modality	EER ± CI 95(%) (Without UCN)	EER ± CI 95(%) (Conventional UCN)	EER ± CI 95(%) (Modified UCN)
Voice (NIST)	30 ± 1.00	11.43 ± 0.70	11.43 ± 0.70
Face (XM2VTS)	3.44 ± 0.39	1.56 ± 0.27	1.56 ± 0.27
Fusing by SVM	3.71 ± 0.41	1.43 ± 0.26	1.13 ± 0.23

It is observed from the results in Table 1, that the use of conventional/ modified UCN has resulted in reducing the verification EERs for the individual modalities and for the fused biometrics. An interesting aspect of these results is that the use of modified UCN does not change the EER for any of the single modalities offered by the conventional UCN. However, it successfully reduces EER for the fused biometrics. The reason for this phenomenon can be described as follows. Firstly, like the conventional UCN, modified UCN cannot be expected to correct any misclassified score for the individual modalities. However, what is achieved through modified UCN is a combination of suppressing the impostor scores in relation to the client ones, and enhancing the client scores when these are affected by data degradation. The enhancement process is carefully accomplished such that the degraded scores are not shifted away from their original class. The combination of the above two characteristics of improved UCN suggests that the technique can help increase the multimodal biometric accuracy. This is, as said earlier, because the technique operates on the individual biometric scores involved independently, and the accuracy of the final fused score in multimodal recognition can benefit from the enhancement achieved in all these individual scores.

It is noted that with conventional UCN, the fusion process results in improving the EER associated with the better modality by about 58%. On the other hand, the reduction in EER achieved with improved UCN is in excess of 67%.

Table 2 presents the results of open-set identification (OSI) experiments. These are expressed in terms of IER (identification error rate) and OSI-EER that occur in the first and second stages of the process respectively.

Table (2)
Experimental results for open-set identification
based on mixed-quality data

Modality	Without UCN		Conventional UCN		Modified UCN	
	IER%	OSI-EER ± CI 95(%)	IER%	OSI-EER ± CI 95(%)	IER%	OSI-EER ± CI 95(%)
Voice (NIST)	45.71	41.43 ± 1.08	45.71	15.56 ± 0.79	45.71	15.56 ± 0.79
Face (XM2VTS)	12.86	11.11 ± 0.69	12.86	3.57 ± 0.41	12.86	3.57 ± 0.41
Fusing by SVM	11.43	8.89 ± 0.62	6.43	3.57 ± 0.41	5.71	1.43 ± 0.26

As observed, the use of either conventional or modified UCN does not change the IER for any of the single modalities whilst, it successfully reduces IER for the fused biometrics. The lowest IER and OSI-EER are obtained when the fusion is based on the use of improved UCN. It is noted that IER and OSI-EER obtained with SVM-based fusion are reduced by 50% and 83% respectively when improved UCN is incorporated into the process.

4. Conclusion :

This paper has presented an investigation into improving the effectiveness of unconstrained score normalisation (UCN) in the fusion-based biometrics. Amongst the two score normalisation methods considered (conventional UCN and modified UCN), modified UCN approach has appeared to offer considerable improvements to the accuracy of multimodal biometrics in varied data conditions. This is shown to be due to the twofold characteristic of this modified score normalisation method. Firstly it aims to suppress the scores from impostors in relation to those for clients, and secondly, it provides a means for enhancing the scores when the test data is degraded. The enhancement process is carefully accomplished such that the degraded scores are not shifted away from their original class. The investigations have confirmed that the accuracy of the final fused score in multimodal recognition can benefit from the enhancement achieved in the individual scores.

Encouraging initial results of the improved UCN approach motivate further research in order to appropriately correct the scores from the degraded modality.

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تعزيز أنظمة الوسائط الحيوية المتعددة بتحسين تقنية التطبيع الغير مقيد

فواز الصاعدي
كلية علوم الحاسب وتقنية المعلومات، جامعة الملك فيصل
الأحساء – المملكة العربية السعودية

الملخص :

أحد العوامل المهمة والتي تؤثر على أداء الوسائط الحيوية المتعددة هو اختلاف (تغير) نوعية البيانات في كل وحدة حيوية على حده. يقترح هذا البحث تحسين تقنية تطبيع الدرجة للحد من آثار اختلاف نوعية البيانات عند عملية الدمج. ومن هذا يتضح أن تطبيق هذه التقنية على مستوى الدرجة يقلل من الآثار السلبية لتغير نوعية البيانات في الوحدات الحيوية المشتركة في الدمج. التجارب تنطوي على اثنين من وسائل التعرف على الأشخاص وهي: التحقق من الهوية و تحديد هوية الشخص. هذه التجارب تمت باستخدام بيانات مختلفة الجودة (النوعية). يعرض هذا البحث الدافع و المزايا المحتملة للنهج المقترح و تقدم أيضا تفاصيل للتجارب التي أجريت.

الكلمات الرئيسية :

متعددة الوسائط الحيوية ، دمج على مستوى الدرجة ، التطبيع الغير مقيد ، التحقق من الهوية.