Abstract

Biometrics is rapidly gaining popularity due to increasing breaches of traditional security systems and the decreasing costs of sensors. Among the biometric traits, the ear and the face are considered the most socially accepted due to their feature richness as well as the possibility of easy and non-intrusive data acquisition. Their proximity also makes them good candidates for fusion. However, occlusions due to non-neutral expressions and the presence of hair and ornaments pose great challenges to apply the face and the ear respectively in real-life applications. These challenges are addressed in this dissertation through the development of efficient and robust algorithms for ear detection, ear data representation and finally, combining it with face biometrics using robust fusion techniques.

In this dissertation, a fast and fully automatic approach for detecting 3D ear from the corresponding 2D profile images using a Cascade AdaBoost algorithm is proposed. The classifiers are trained with three new Haar-like features and the detection is made using a $16 \times 24$ detection window placed around the ear. The approach is significantly robust to hair, earrings and earphones and unlike other approaches, it does not require making any assumption about the localization of the nose or the ear pit. For recognition, we initially propose to apply the Iterative Closest Point (ICP) algorithm in a hierarchical manner: first with a low and then with a higher resolution of meshes of 3D ear data. Results obtained in the first stage are used for coarse alignment for the next and thus computational expense of this more accurate but iterative algorithm is reduced. In order to achieve better efficiency and robustness to occlusions, 3D local features (L3DFs) are used for data representation and matching. Local features are used to develop a rejection classifier, to extract a minimal rectangular feature-rich region and to compute the initial transformation for the ICP algorithm. An improved technique for feature matching is also proposed using geometric consistency among the corresponding features. While evaluating the performance of the proposed approaches, we obtain a detection rate of 99.9% on the UND-J Biometrics Database with 830 images of 415 subjects (the largest publicly available profile database) taking only 7.7 ms on average using a C++ implementation on a Core 2 Quad 9550, 2.83 GHz PC. On the same database, we obtain an identification rate of 93.5% with an Equal Error Rate (EER) of 4.1%. Corresponding rates on a new dataset of 50 subjects all wearing ear-phones are 98% and 1%. With an un-optimized MATLAB implementation, the average time required for the L3DF-based matching and for the full matching including ICP are 0.06 and 2.28 seconds respectively.
In order to increase the robustness further, two techniques have been presented to fuse the ear with face biometrics. In score-level fusion, scores from the face are computed using the same matching technique proposed for the ear and a weighted sum rule with some complementary weights is used for fusion. For the fusion of the ear and the face local features (feature-level fusion), the shape similarity among the local features from the two different modalities is utilized in the construction of the multimodal ear-face gallery and probe datasets prior to applying concatenation. Matching is performed using similar L3df-based similarity measures as the ones used in the case of unimodal matching. An accuracy of 99.4% and 99.7% identification and a verification rates (on a multimodal dataset with 326 subjects constructed using common data between FRGC v.2 and the UND-J databases) are obtained in the score-level fusion of the two modalities. Better efficiency is obtained with a slightly lower accuracy of 98.4% and 97.8% identification and verification results respectively in case of feature-level fusion.

The unimodal and multimodal approaches proposed in this dissertation for ear and face biometrics can be extended for recognition with other similar biometric traits and objects and for other applications such as robotics, medicine and forensic sciences.