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A 3D face and hand biometric system for robust user-friendly authentication

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Abstract

A complete authentication system based on fusion of 3D face and hand biometrics is presented and evaluated in this paper. The system relies on a low cost real-time sensor, which can simultaneously acquire a pair of depth and color images of the scene. By combining 2D and 3D facial and hand geometry features, we are able to provide highly reliable user authentication robust to appearance and environmental variations. The design of the proposed system addresses two basic requirements of biometric technologies: dependable performance under real-world conditions along with user convenience. Experimental evaluation on an extensive database recorded in a real working environment demonstrates the superiority of the proposed multimodal scheme against unimodal classifiers in the presence of numerous appearance and environmental variations, thus making the proposed system an ideal solution for a wide range of real-world applications, from high-security to personalization of services and attendance control.

Keywords: Multimodal biometrics; 3D face; 3D hand geometry; Color images; Classifier fusion; Score normalization

1. Introduction

The use of biometric technologies for personal authentication has been an ongoing topic of research, mainly due to the increasing number of real-world applications requiring reliable authentication of humans. Although biometric authentication has been extensively used in high-security systems, its use in everyday applications, such as access control in buildings, tracking attendance or user personalization, was until recently rather limited. This can be mainly attributed to the fact that high performance biometrics such as the iris or fingerprint do not enjoy user acceptance, since they are highly obtrusive, while other friendlier biometrics, such as the face, may not be reliable under real-world conditions.

Since user acceptance and convenience is a decisive parameter in designing a biometric system suitable for a wide range of applications, much effort has been devoted to personal authentication based on images of the human face and many algorithms to this end have been proposed (Zhao et al., 2003). The majority of these techniques rely on 2D gray-scale images. Recent public face recognition benchmarks demonstrated that the performance of the best 2D face recognition algorithms is similar to that of fingerprint recognition, when frontal homogeneously illuminated views are used, but degrades significantly for images subject to pose, illumination or facial expressions variations (Phillips et al., 2003). To improve performance under these conditions, the use of 3D facial images was proposed, based on the fact that the 3D structure of the human face can be highly discriminatory and is inherently insensitive to

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illumination variations and face pigment. Moreover, 3D information can significantly aid pose estimation (Bowyer et al., 2006).

The earliest approach towards 3D face recognition is based on computation of the surface curvature, which is subsequently used for the localization of facial features (Kim et al., 2001), the construction of Extended Gaussian Images (Tanaka et al., 1998) or the extraction of local Point Signatures (Chua et al., 2000). Although, high recognition rates were reported for these techniques, in practice curvature-based methods are very sensitive to image noise and occlusions of the face.

The iterative closest point (ICP) algorithm, which is widely used for registration of 3D models, is also employed by many 3D face recognition techniques (Medioni and Waupotitsch, 2003). The matching efficiency of the ICP is improved by considering additional features, such as color or curvature, or by using a weighted distance (Lu et al., 2006). In (Chang et al., 2005), a recognition rate of 92% is claimed in a database of 4000 images belonging to 477 individuals.

Appearance based methods like PCA or Fisherfaces have also been proposed (Heseltine et al., 2004; Chang et al., 2003). The main problem of these techniques is alignment of 3D images and pose variations, usually solved by manual detection of facial features such as the eyes, nose or mouth. In (Chang et al., 2003), a recognition rate of 93% is obtained in a test set comprised of 950 frontal views of 200 people. Other approaches include the use of deformable 3D models (Passalis et al., 2005) or techniques based on the isometry assumption and use of geodesic distances (Bronstein et al., 2005). In (Passalis et al., 2005), a 90% recognition is reported in a database of 3500 images.

The combination of 2D and 3D data for face recognition was also investigated and significant improvements have been reported (Tsalakanidou et al., 2005b; Chang et al., 2003). Multimodal techniques usually rely on fusion of scores obtained by unimodal classifiers, disregarding the actual information conveyed by the two modalities. In an attempt to exploit the main advantage of 3D face geometry, i.e. relative robustness to viewpoint and illumination changes, a novel face authentication system integrating 2D and 3D images was proposed by the authors in (Tsalakanidou et al., 2005a; Malassiotis and Strintzis, 2005). The combination of 2D and 3D facial data, along with treatment of illumination and pose variations resulted in significant gains in terms of system performance, but still did not cope with other sources of variation, e.g. presence of facial expressions, change of appearance due to time and occlusions.

To improve authentication accuracy, we propose the combination of the above 3D face authentication system with another user-friendly biometric modality: hand geometry. Systems based on hand geometry are very popular and are widely implemented for their ease of use, public acceptance and integration capabilities. However, such systems present several shortcomings, the most important being that hand geometry features are not highly distinctive, thus preventing the use of this modality for high-security applications.

Another argument against the use of hand recognition systems for personal identification is their obtrusiveness imposed by the use of special devices for placing the user's palm, such as platters with knobs or pegs (Sanchez-Reillo et al., 2000). These devices, however, simplify the process of feature extraction, which is usually based on the analysis of image contours of hand views. Various features such as the width of the fingers, length of the fingers and width of the palm have been proposed. Satisfactory recognition results are obtained (96% for recognition and less than 5% EER for authentication). Hand silhouettes have also been employed (Jain and Duta, 1999).

Document scanners have also been proposed for the acquisition of hand images (Oden et al., 2003; Bulatov et al., 2004). In (Bulatov et al., 2004) a feature-based approach is used and an FRR close to 3% was achieved for an FAR of 1% on a database of 70 people. In (Oden et al., 2003), implicit polynomials are fitted on hand contours and geometric invariants are subsequently computed from these polynomials. An FRR of 1% for an FAR of 1% on a small database (45 images) is reported.

A touch-free technique is proposed in (Zheng et al., 2004). It is based on the localization of finger creases on the front size of the palm. Zero FAR for an FRR of 2.8% is claimed on a small dataset. In (Woodard and Flynn, 2004), a 3D scanner is used to acquire a range image of the back of the hand placed on a dark surface. Recognition is based on curvature measurements of fingers. For images acquired on the same week the recognition rate was 99.4%, but dropped to 75% when probe and gallery images were acquired with one week lapse.

A novel, unobtrusive hand recognition system based on 3D images of the user's hand acquired using the low-cost 3D sensor of Tsalakanidou et al. (2005a) was proposed by the authors in (Malassiotis et al., 2006). The experimental evaluation showed that the system's performance was comparable to that of other state-of-the-art hand geometry systems.

In this paper, we propose the integration of the aforementioned 3D face and hand geometry recognition algorithms in a novel multimodal biometric system, which combines high authentication reliability with user convenience and acceptance. Multimodal authentication based on face and hand geometry was also investigated elsewhere (Jain et al., 2005; Ross and Jain, 2003), but it was only tested under ideal conditions regarding both appearance variations and environmental conditions. Moreover, face recognition was based on a CCD camera, while hand recognition relied on placement of the user's hand on a special platter with knobs or pegs constraining the hand's positioning on the platter. 2D images of the face and the hand were used for extracting facial and hand geometry features, thus making the system sensitive to illumination changes.