

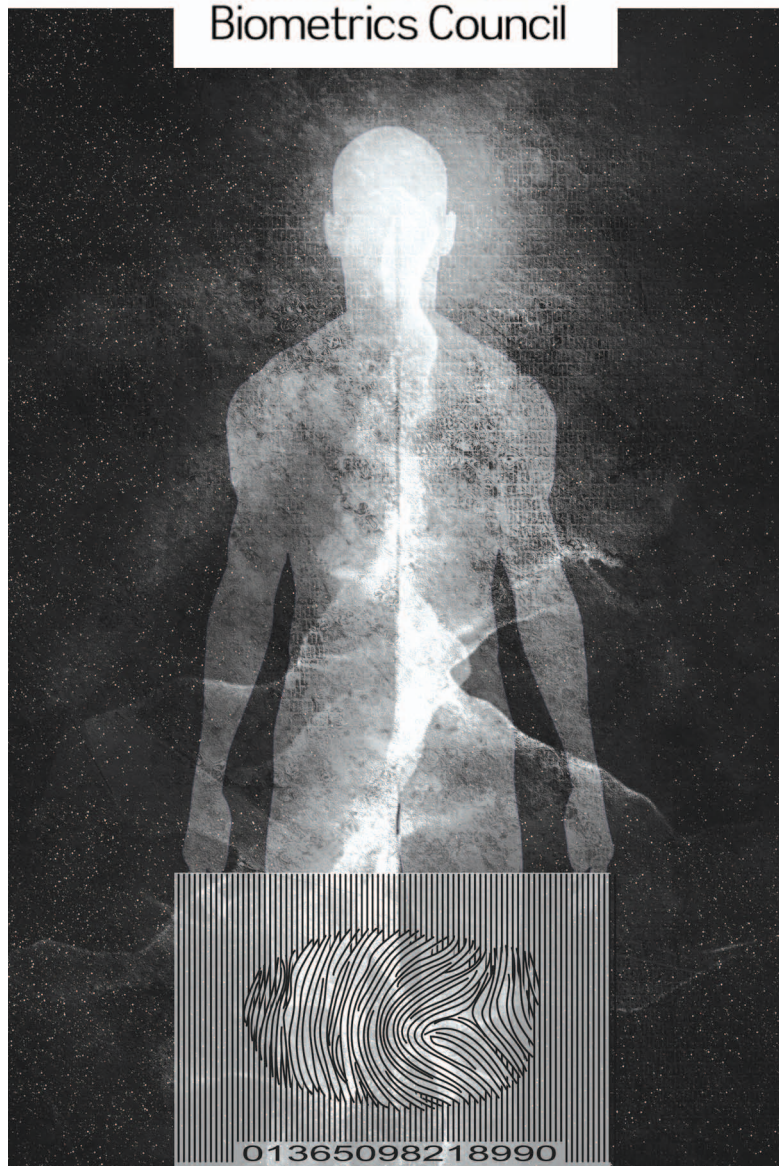
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IEEE BIOMETRICS COMPENDIUM IS THE FIRST IEEE virtual journal, which is a collection of previously published IEEE papers in specific scientific and technical disciplines paired with value-added commentary from technology experts. The compendium is published quarterly by the IEEE Biometrics Council, which was originally created and sponsored by a consortium of IEEE Societies. The IEEE Consumer Electronics Society was one of the founding members/sponsors of the Council. The compendium highlights various specific areas in biometrics and contains commentary from subject experts on the IEEE Biometrics Council. Subscribers receive access to full-text pdf files of all articles referenced from the current and past years. The compendium is an excellent resource to find all biometrics-related research publications in a single place.

At present, the compendium is not included in your Society membership, but you can obtain a low-cost individual membership. For IEEE and Society members, this costs US\$30, IEEE Student Members pay a subsidized US\$15, and nonmembers and organizations pay the full membership rate of US\$270.

To give you an idea of what you can expect to find in the compendium, this article will provide an insight into the current issue, which, in turn, will give you an idea of the broad topics covered in each quarterly issue and a feeling for the broad scope of material referenced. Note that this is condensed significantly in size from the full issue, providing a snapshot rather than the entire photo album.



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Introducing *IEEE* *Biometrics Compendium*

Insight into the current issue.

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WHY WOULD I WANT THE COMPENDIUM?

A good question! Well, if you are doing research in the field of biometrics, a subscription to the compendium is very likely to be high on your wish list.

Why? Because it is just like having 1) a super-journal that specializes in biometrics, drawing its content from the widest imaginable range of IEEE journals (e.g., Figure 1); 2) even better, a group of subject experts who will trawl through all and any IEEE journals to bring you the best and most recent research publications relating to biometrics; and 3) better still, these subject experts provide commentary, analysis, and context for the papers they select for the compendium, making your job of finding publications relevant to

your own research work a no-brainer. Best of all, this costs you a small annual fee with a 50% reduction for students.

In practical terms, you not only get a subscription to more than a dozen IEEE publications spread across many IEEE Societies but also the benefit of all the expert editors and reviewers who are involved in the compendium and whose mission is to bring you the best and most topical research in biometrics today. However, it is very difficult to fully appreciate the nature and scope of this material until you actually get to read or review a copy of the compendium.

Here, we are giving you the next-best thing—a shortened and somewhat truncated synopsis of the latest quarterly *IEEE Biometrics Compendium*. It is not quite the real thing, but



FIGURE 1. Cover pages from some of the main IEEE publications that contribute to the *IEEE Biometrics Compendium*.

perhaps the next few pages of this article will inspire you to seek out the original of the species.

FACE DETECTION AND ANALYSIS

Face recognition is a challenging problem that has been actively researched for more than two decades. Current systems work very well when the test image is captured under controlled conditions. However, their performance degrades when the test image contains variations that are not present in the training images.

Some of these variations include illumination, pose, expression, occlusion, aging, disguises, etc. In the current issue, we discuss some recent papers on face and facial expression recognition divided into the following sections: face detection, representation, face tracking, two-dimensional (2-D) face recognition, 2.5-D face recognition, 3-D face recognition, and facial expression.

FACE DETECTION

Face detection from still and video images has been extensively studied using data collected by conventional perspective cameras. Dupuis et al. [4] study the problem of face detection using data collected by omnidirectional sensors, which are increasingly being used for surveillance applications. They make the argument that if features used for omnidirectional cameras are chosen properly, then face/object detection using omnidirectional data can be quite effective.

FACIAL REPRESENTATION

Facial landmarks are essential for face alignment: face matching as well as modeling facial aging. Although there are several methods in the literature for detecting facial landmarks, many of them are not effective when pose variations are present; also, many feature detection methods do not cope well with facial expressions. The PAMI paper by Sangineto [18] presents an effective method for facial landmark detection under pose and expression variations by combining 3-D models of faces and dense SURF. Comparisons with SIFT and other SURF feature-based methods using XM2VTS, the BioID, the artificial driver data sets, and face data collected by the author are provided. One of the best features of this method is the exploitation of constraints generated by the 3-D shape.

The choice of global versus local features has been a topic of much discussion in human and machine perception of faces and facial expressions. Principal component analysis and discriminant analysis are some of the well-known examples of global features. Gabor features and local binary patterns have been effective as local features. Recently emerging representations based on dictionaries can accommodate both global and local features based on what is available.

The IP paper by Rivera et al. [17] proposes a local feature descriptor, local directional number pattern (LDN), for face and expression recognition. The LDN feature, inspired by local binary pattern representation, encodes the directional information of the face's textures and is claimed to be more discriminative than current methods. The results using the

FERET, Yale B, Extended Yale B, LFW, and CAS-PEAL databases are presented. Performance improvements vary depending on the data set.

The IFS paper by Vu [27] presents a similar local approach based on gradient orientations and magnitudes of different local image structures. The author evaluates the so-called patterns of oriented differences (POD) and also suggests several improvements to another class of local features known as patterns of oriented edge magnitudes (POEM) suggested by him earlier. After performing dimensionality reduction using PCA, experimental results using POD, POEM, and a combination of POD and POEM are given using frontal and nonfrontal FERET data and the more challenging LFW data set. The paper makes extensive comparisons with many existing approaches on these two data sets.

FACE TRACKING

In many practical video surveillance applications, the faces acquired by outdoor cameras are of low resolution and are affected by uncontrolled illumination. Although significant efforts have been made to facilitate face tracking or illumination normalization in unconstrained videos, the approaches developed may not be effective in video surveillance applications.

The IP paper by Zou et al. [32] performs tracking in an illumination insensitive feature space, called the gradient logarithm field (GLF) feature space. The GLF feature mostly depends on the intrinsic characteristics of a face and is only marginally affected by the lighting source. In addition, the GLF feature is a global feature and does not depend on a specific face model, and thus is effective in tracking low-resolution faces. The experimental results show that the proposed GLF-based tracker works well under significant illumination changes and outperforms many state-of-the-art tracking algorithms.

FACE RECOGNITION

Classical methods based on Fisher faces require several images of a subject. In many practical applications, only one face image per person might be available. The PAMI paper by Lu et al. [14] presents a discriminative multimanifold approach for face recognition when only one gallery image per subject is available. The proposed approach divides a given face into overlapping patches and converts the face recognition problem into one based on image sets constructed from the patches. Results on faces from the AR, FERET, and FG-Net databases are provided.

Albedo estimation from a face image has been considered in several recent papers for designing robust algorithms for face recognition. Many of these algorithms assume a Lambertian model and ignore cast or attached shadows. The IP paper by Suh et al. [22] proposes a linear programming solution to albedo estimation in the presence of cast shadows. Experimental results using the FRGC and Bosphorus data sets are given to validate the proposed method. This method can be extended for multiple light sources, multiple images, and video sequences.

When faces are acquired at distances larger than 50 m, they are often degraded because of blur and illumination

variations. The traditional approach for recognizing such degraded faces is to deconvolve them and then apply a standard face recognition method. This is a difficult problem as the point spread function that characterizes the blurred face is severely ill-conditioned, and hence, the deconvolved face may contain artifacts.

The IP paper by Vageeswaran et al. [26] presents a direct approach for recognizing blurred faces that are also corrupted by illumination variations. The authors first show that the set of all images obtained by blurring a given image forms a convex set. Based on this set-theoretic characterization, a blur-robust algorithm whose main step involves solving simple convex optimization problems is proposed without assuming any parametric form for the blur kernels.

One of the key challenges for current face recognition techniques is how to handle pose variations between the probe and gallery face images. The most popular method for aligning a nonfrontal face to a frontal face is the 3-D morphable model-based approach, which usually needs six points to be manually extracted from the faces. The IP paper by Ho and Chellappa [6] presents a method for reconstructing the virtual frontal view from a given nonfrontal face image using Markov random fields (MRFs) and an efficient variant of the belief propagation algorithm. This method does not require manually selected facial landmarks or head pose estimation. Experimental results on different data sets are presented to demonstrate the effectiveness of the proposed approach.

2.5-D FACE RECOGNITION

Concepts drawn from shape from shading and photometric stereo have been considered for face recognition for more than ten years. The IFS paper by Zafeiriou et al. [30] presents a comprehensive discussion of the effectiveness of photometric stereo-based methods for face recognition and verification. The authors first describe an experimental setup for collecting images using a photometric setup. They then discuss face recognition/verification results using the albedo as well as the depth data and normal vectors. While constructing surfaces from normal vectors, the authors evaluate several classical and recent algorithms. They conclude that if only one image per subject is available, the albedo-based algorithm is more effective. If two images per subject are available, the performance across the different modalities is almost the same. They also note that the difference in performance when depth or surface normal is used is not significant. The data set collected by the authors will inspire more research on how 2.5-D data can be exploited for face recognition/verification.

3-D FACE RECOGNITION

The PAMI paper by Mohammadzade and Hatzinakos [15] presents a method for 3-D face recognition using surface normal vectors from the query image that are closest to a reference 3-D face in the discriminant analysis (DA) framework. Comparisons to PCA and range-based methods show the superiority of the DA method over several existing methods for the FRGC data set.

The PAMI paper by Ocegueda et al. [16] presents a novel approach for deciding whether a pixel possesses the discriminative power (or not) for a given classification problem by posing the problem as a binary segmentation using MRFs. The binary label 1 corresponds to the pixel possessing discriminative power, while the label 0 corresponds to when the pixel does not possess any discriminative power. It is hypothesized that pixels that are discriminative (or not) come in groups, which enables the definition of prior distribution in computations leading up to the evaluation of posterior marginal.

The IP paper by Sun et al. [23] presents a nonlinear least squares method for estimating a 3-D model of a face from one or more 2-D images. The proposed method uses facial symmetry and constraints derived from the 3-D Candide face model for regularizing the optimization formulation. The method is evaluated based on the accuracy of the estimated depth values, effectiveness as a pose estimator, and performance in 2-D and 3-D face recognition. Experimental results using FERET and Bosphorus data sets are provided as well as comparisons with a recent shape from shading algorithm for estimating the 3-D structure of a face.

Spherical harmonics have been traditionally used for characterizing illumination variations in 2-D face recognition. The IP paper by Liu et al. [13] proposes a method for 3-D face recognition using SHREC2007, and Bosphorus data sets.

Features based on isodepth curves were suggested for 3-D recognition by Gordan more than two decades ago, and more recently, the elastic curves were suggested by Srivastava's group. The IFS paper by Berretti et al. [2] proposes a method for 3-D face recognition in the presence of missing regions using features that characterize the variations of facial curves that connect keypoints in 3-D face data. The results using the FRGC and Gavab data sets are presented.

FACIAL EXPRESSIONS

A synthesis-based approach for 3-D expression recognition is discussed in the CSVT paper by Tie and Guan [25]. In this work, 26 fiducial points are tracked using particle filters. The fiducial points on the facial region correspond to those with maximum movement of the facial muscles during expressions. To ensure robustness, an additional 28 points (determined by the fiducial points) were extracted for characterizing the facial expressions. The tracked points are embedded into the elastic body spline approach originally used in interpreting MRI images for deriving deformable features corresponding to a given expression. These features are subsequently classified using a variant of an Isomap algorithm. The results using two data sets are reported.

IRIS/OCULAR RECOGNITION

Robustly estimating iris masks is a key factor for iris recognition effectiveness, and previous works have reported degradation in performance when artifacts are considered in the signature encoding phase. Most frequently, such artifacts augment the false rejection rates, but they can even augment the number of false acceptances if adaptive thresholds with respect to the amount of unoccluded iris are used. According to this, Li

and Savvides [12] propose a method to discriminate the useful parts of the normalized iris images acquired under noncontrolled conditions. Having considered that previous approaches are rule based and have questionable effectiveness, they use Figueiredo and Jain's Gaussian Mixture Models to model the underlying probabilistic distributions of valid and invalid regions of the irises represented in the pseudopolar space.

IRIS SEGMENTATION AND GEOMETRY

Tan and Kumar [24] present an iris segmentation strategy for iris data acquired at large distances in both near-infrared and visible light. After applying an initial color constancy technique, the main concept of the process is the Grow-Cut algorithm that, on some initialization, is able to discriminate between foreground (iris) and background (noniris) data.

The work of Kong [11] primarily aims to provide a deeper understanding of the geometric structures of the IrisCode and its variants, seeking to analyze the potential security and privacy risks from this geometric information. In this context, the term IrisCode refers to the binary biometric signature that yields from the convolution of the iris data by a bank of Gabor filters, generating complex-valued coefficients that are further quantized.

IRIS ACQUISITION

Gong et al. [31] describe an empirical process to find the light wavelengths that best describe the texture of heavily pigmented iris images. They devise a multispectral acquisition system in the range from 420 to 940 nm and use 100 subjects with heavily pigmented irises as the main source for their experiments. Their experiments suggest that 700 nm is the most suitable wavelength for heavily pigmented irises. This work suggests that new recognition approaches might use soft biometric information (such as race, gender, or levels of iris pigmentation) to switch between the wavelengths used in the signature encoding process.

Huang et al. [7] address the problem of less intrusive iris image acquisition. More specifically, the given contributions of the paper are twofold: 1) an iris segmentation method that works at very different image resolutions (from 50 to 350 pixels in iris diameter). This part starts by detecting a set of edges (Canny detector), whose nonconnected components are considered nodes of a graph. Next, on the basis of the normalized cuts criterion, they discriminate between the most probable circlelike shapes that correspond to the iris boundaries and 2) describe the segmented and normalized iris images in terms of intensity and geometric transforms, low-pass filters, and normalization artifacts plus additive noise. This framework is used as a basis for a feature selection phase, according to the real parts of the Log-Gabor filters responses.

EYE TRACKING FOR IRIS RECOGNITION

The results of the first competition about biometric recognition based on eye movements are given by Kasprowski et al. [10]. As organizers of this competition, the authors highlight the importance of very careful eye positional data capture,

which might lead to notorious changes in the identification performance (between 58.6% and 97.7%).

ARTIFACTS AND ACQUISITION QUALITY

The effect of plastic surgery in the effectiveness of biometric identification is handled by Jillela and Ross [9]. Considering that the existing approaches are computationally expensive because of their machine-learning nature, the authors propose a fusion approach that combines information from the face and ocular regions. Regarding the ocular region, data were encoded by three well-known methods in the field: SIFT, histograms of oriented gradients, and local binary patterns.

The work of Santos-Villalobos et al. [19] aims to handle the off-axis effect of iris data acquired under less constrained setups. Their method is based on ray tracing techniques and in a generalized model of the human eye, developed at ORNL, known as the ORNL Eye. Given an off-angle image, this model is used to obtain a nonrigid transform that enables reconstruction of the iris from off-axis and refraction deformations. As that transformation is found, their method renders a frontal view of the reconstructed iris.

FINGERPRINT ANALYSIS

In the first quarter of 2013, the fingerprint biometric field had five papers published in IEEE journals, ten in the IEEE Fifth International Conference on Biometrics: Theory, Applications, and Systems (BTAS 2012), and three in the Fourth IEEE International Workshop on Information Forensics and Security (WIFS 2012). These papers span a wide range of topics: from feature extraction to latent fingerprints, from fingerprint retrieval to fingerprint matching, and from usability experiments to synthetic generation.

Feature extraction in low-quality fingerprints continues to be a very challenging problem: Bartunek et al. [1] introduce a fingerprint enhancement method based on spatial contextual filtering by means of matched directional filters, while, in [28], the authors propose first to enhance the fingerprint in the spatial domain and then to perform a second enhancement stage in the frequency domain (Figure 2).

CONFERENCE PAPERS FROM BTAS

At BTAS 2012, Cao et al. [3] presented a new method for smoothing fingerprint orientation fields. Reliable extraction of local orientations from low-quality fingerprints is a challenging and very important problem. In fact, estimation of ridge-line orientations can be probably considered the most critical feature extraction step in fingerprint recognition. The method proposed by Cao et al. [3] is based on the analysis of divergence and curl of the orientation field and on an adaptive filtering process that takes into account the distance from the fingerprint core.

Other BTAS 2012 papers related to fingerprint feature extraction include: Short et al. [20], in which the authors propose a ridge-line following technique to extract minutiae based on Bayesian prediction, and Gupta and Gupta [5], in which a technique is introduced to segment a slap-image into individual

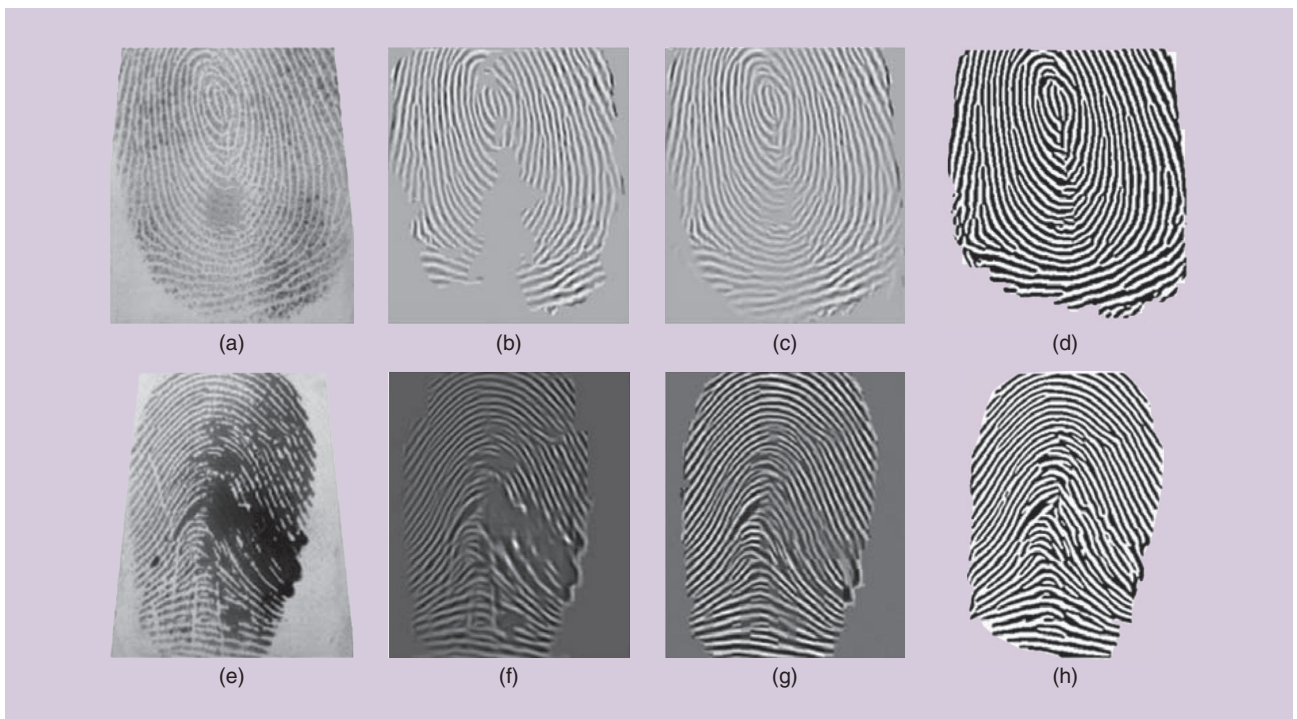


FIGURE 2. Fingerprint enhancement. (a) The original fingerprint, (b) the result using a previously published enhancement method, (c) the result using the method proposed in Bartunek et al. [1], (d) an enhancement using two passes of contextual convolution with Gabor filters, (e) the original fingerprint, (f) the result using the traditional Hong's Gabor filter-based algorithm, (g) the result using the method proposed in Yang et al. [28], and (h) an enhancement using two passes of contextual convolution with Gabor filters.

fingerprints of the four fingers. Finally, in a paper presented at WIFS 2012, Si et al. [21] propose a method of extracting specific features to detect fingerprint distortion, a perturbation that undermines matching accuracy and is not detected by current fingerprint image quality assessment algorithms.

Two papers presented at BTAS 2012 deal with fingerprint retrieval and matching. In Yuan et al. [29], a fingerprint retrieval technique based on minutiae triplets was introduced that is designed to speed up fingerprint identification over large databases. The experimental results show that the proposed approach competes with the state of the art. It would be interesting to see the performance of this approach on the new FVC-onGoing fingerprint indexing benchmark. Izadi et al. [8] propose a method to associate local quality measures to Minutia-Cylinder Code (MCC) descriptors to obtain better recognition rates.

COMMENTS

This article is a shortened and very truncated synopsis of the latest quarterly *IEEE Biometrics Compendium*. It is not quite the real thing, but perhaps the material and references presented in this article will inspire you to seek out the original of the species. With an active subscription, you get access to all of the original articles cited in these research commentaries and you get a lot more summary material under each topic.

The full compendium includes additional and more detailed material on each of the traditional biometric topics that have been covered here; it also adds commentary on emerging topics and technologies of interest to the biometrics community. This particular issue includes detailed commentary on

additional topics such as emerging biometrics, multibiometrics, performance evaluation, biometrics data sets, and security of biometric systems. In addition, the coverage to all topics gives much more in-depth commentary and analysis than can be presented in this article.

If you work in biometrics research, it is very likely that you would benefit from the low-cost individual membership—please see *IEEE Xplore* for details. Alternatively, you should check with your institutional or organizational library to ensure that their subscription includes access to the compendium. It really is your one-stop source across IEEE for all things biometric.

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