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Editorial to special issue on novel insights on ocular biometrics

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Editorial to Special Issue on Novel Insights on Ocular Biometrics in *Image and Vision Computing*

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Ocular biometrics have a great potential to support biometric applications, due to the unique features of the ocular traits. Notwithstanding this, the related lines of research still present several open issues, which justify the ongoing research efforts. For instance, the relatively recent emergence of the periocular and sclera traits makes it worth recording the progresses in those areas. Furthermore, wider and deeper investigations regarding all the traits underlying the ocular region and the best way to combine them still needs to be thoroughly undertaken. This would not only improve the recognition robustness, but also make perceiving the potential of this kind of solutions in solving problems in the biometrics domain. Moreover, "systems interpretability", "weakly/partial supervised recognition" or "forensics evidence and biometric recognition" add interest to an already rich field of research. This special issue aims at providing a platform to publish and record the recent research on ocular biometrics in order to push the state-of-the-art forward.

Highlights of the special issue

Responding to the call, various articles were submitted tackling different challenges in the aforementioned domain. Among these, after peer review 13 articles were selected to be included in this special issue. The works in this issue can be broadly classified into three groups: (a) articles analyzing the iris and sclera regions, (b) articles covering the periocular region, and (c) articles addressing generic engineering aspects of ocular biometrics.

Iris and sclera region

Four articles of the special issue tackle problems related to the use of the iris and sclera regions. These works follow the classical belief that the iris is the most reliable trait in the ocular area and hence it is a primary candidate to be used in feature extraction/matching.

The article titled "*Whether normalized or not? Towards more robust iris recognition using dynamic programming*" by Chen *et al.* [1] describes a non-normalized preprocessing method based on dynamic path search for iris segmentation. The article proposes to deploy a deep convolutional network (DCNN) based on partial convolution operators to extract iris features. Interestingly, authors claim that using iris segmentation images without normalization may be a good choice while considering deep learning for iris recognition.

The second article titled "*Demographic classification through pupil analysis*" by Cantoni *et al.* [2] attempts to exploit the pupil size as a discriminating feature to estimate gender and age via training two classifiers: Adaboost and SVM. The experiments involving more than 100 participants lead the authors to conclude that pupil size can provide significant results. Three types of features are considered while characterizing pupil: PDM (Pupil Diameter Mean), PDR (Pupil Diameter Ratio), and PDO (Pupil Diameter Order). Among these, the PDM outperformed the others for both gender- and age- related experiments.

Another article under this section titled "*Cross-database and cross-attack iris presentation attack detection using micro stripes analyses*" by Fang *et al.* [3] proposes a framework for detecting iris contact lens-based presentation attacks (PAD) based on the majority vote of normalized multiple micro stripes. The authors provide a rationalization of the proposed method by studying the significance of different pupil-centered eye areas in iris PAD decisions under various experimental settings. In addition, extensive cross-database and cross-attack detection evaluation experiments were carried out to explore the generalizability of the proposed methods upon texture-based methods and neural network based methods. In this setting, the Micro Stripes Analyses (MSA) method is found to optimally generalize, when compared to other baselines.

The last article in this section titled "*Cancelable iris template generation by aggregating patch level ordinal relations with its holistically extended performance and security analysis*" by Singh *et al.* [4] proposes a cancelable iris biometric authentication system that stores a transformed version of the original iris template and enables cancelation and re-enrolment if the original template is compromised. Iris features based on ordinal analysis are protected using state-of-the-art cancelable biometric techniques, viz., BioHashing and 2N discretized BioPhasor. Authors claim that the performance of the proposed technique achieves significant improvement compared to the state-of-the-art.

Periocular region

The six following articles of the special issue consider the periocular region as the major information source. These articles propose novel features to be used for recognition, and analyze the possibility of fusion with other traits.

The first article titled "*Generalizable deep features for ocular biometrics*" by Reddy *et al.* [5] presents an efficient deep learning-based feature extraction pipeline for learning generalizable features for ocular recognition. The proposed pipeline uses a relatively less parameterized Convolutional Neural Network (CNN)-based feature extraction model along with a region of interest (ROI) detector and data augmenter. The proposed CNN model has 36 times fewer parameters than the popular ResNet-50. Cross-dataset experiments show a reduction of the error rates up to 7 times, when compared to the existing models.

The second article is titled "*Variance guided attention-based twin deep network for cross-spectral periocular recognition*" by Behera *et al.* [6] discusses an attention-based twin deep CNN with shared parameters to match the periocular images in a cross-spectral scenario. The authors introduce a novel variance-guided objective function and an attention module to guide the network to focus on the relevant regions of the periocular images. The weights of the twin model are learned so to reduce the intra-class variance and to increase the inter-class variance of the cross-spectral image pairs. The authors support their claims by the results achieved in ablation studies on cross-spectral periocular datasets containing visible spectrum, near-infrared, and night vision domains.

The third article titled "*Collaborative representation of blur invariant deep sparse features for periocular recognition from smartphones*" by Raja *et al.* [7] presents two novel feature extraction techniques to achieve robust and blur-invariant biometric verification using periocular images captured using smartphones, viz., (1) Deep Sparse Features (DSF) and (2) Deep Sparse Time Frequency Features (DeSTiFF). Both approaches are based on extracting features via convolution of periocular images with a set of filters referred as Deep Sparse Filters. The filters are learnt using natural image patches and sparse filtering approaches. The DSF are generated through the convolution with Deep Sparse Filters. Further, the obtained responses are analyzed using Short Term Fourier Transform (STFT) to obtain time and frequency features referred as DeSTIFF. These features are further represented in a collaborative subspace to achieve better verification performance. Both feature extraction schemes are evaluated on smartphone periocular databases. The authors also introduce a new database to the research community through this article: Visible Spectrum Periocular Image (ViSPer).

The next three articles can be found under this section [8, 9, 10] and conduct experiments towards perceiving the plausibility of fusion for improving the recognition state-of-the-art.

The article titled "*Fusion of iris and sclera using phase intensive rubber sheet mutual exclusion for periocular recognition*" by Jain *et al.* [8], presents a multi-biometric fusion method termed as Phase Intensive Mutual Exclusive Distribution (PI-MED) that combines periocular features (i.e. iris and sclera) for identity verification. The main objective of PI-MED is to reduce the matching and fusion time through score-level fusion and to reduce the overhead during human recognition in biometrics. In this model, feature fusion is generated based on the log likelihood ratio by using covariance matrix measurement. Distributed Hamming Distance Template Matching (DHDTM) algorithm is designed to perform matching.

The article titled "*Iris and periocular biometrics within head mounted displays: Segmentation, recognition, and synthetic generation*" by Boutros *et al.* [9] investigates the possibility of using the ocular images captured from cameras integrated in Head Mounted Display (HMD) devices for biometric verification, taking into account the expected limited computational power of such devices. Such an approach can allow verifying the identity of the user without explicit involvement. The work presents a light weight, yet accurate, segmentation solution for the ocular region captured from HMD devices. The authors also propose an identity-preserving synthetic ocular image generation mechanism that can be used for large-scale data generation for training purposes or attack-based image generation purposes.

The last article in this section titled "*Improving eye movement biometrics in low frame rate eye-tracking devices using periocular and eye blinking features*" by Seha *et al.* [10] evaluates the potential of eye movement patterns extracted from low frame rate eye-tracking devices for biometric recognition. Additionally, the work investigates the improvement in recognition rates that can be achieved by using other static and dynamic features extracted from the eyes, including eye blinking patterns and periocular shape features. Two databases from 55 participants are collected with two low frame rate eye-tracking systems that capture the eye movements. For eye gaze, features from fixations and saccades are extracted separately including duration, amplitude, and related statistical features. In regard to eye blinking, features from the blinking pattern, its speed, acceleration, and power per unit mass profiles are extracted. Periocular features as eye-opening height, width and axial ratio are also considered. These modalities are integrated within a multi-modal setup for performance improvement. The fusion of these traits is claimed to achieve high levels of identification making these traits effective for continuous driver authentication application.

Addressing generic engineering aspects of ocular biometrics

Finally, the following three articles of the special issue cover generic engineering aspects related to augmenting quality of ocular biometrics like liveliness detection, reviewing existing iris datasets and weighing them in terms of several parameters, analyzing requirement of new dataset etc.

The first article under this section titled "*Optokinetic response for mobile device biometric liveness assessment*" by Lowe and Derakhshani [11] showcases a novel optokinetc nystagmus (OKN)-based liveness assessment system for mobile applications that leverages phase-locked temporal features of a unique reflexive behavioral response. This article provides a proof-of-concept for eliciting, collecting and extracting the OKN response motion signature on mobile devices. Additionally, the article also discusses simulated video-based attacks in this context.

The second article titled "*A survey of iris datasets*" by Omelina *et al.* [12] provides a comprehensive overview of the existing publicly available datasets and their popularity in the research community using a bibliometric approach. The authors start by reviewing 158 different iris datasets utilized by most relevant recent researchers in this domain. Then, they taxonomically categorize the datasets and describe the properties important for performing relevant research.

The last article titled "I-*SOCIAL-DB: A labeled database of images collected from websites and social media for iris recognition*" by Labati *et al.* [13] points the attention of the research community to the use of iris-based recognition techniques for images uploaded on websites and social media, which is possible with the current resolution of images. The authors present a public image dataset called I-SOCIAL-DB (Iris Social Database) composed of 3,286 ocular regions, extracted from 1,643 high-resolution face images of 400 individuals, collected from public websites. For each ocular region, a human expert extracted the coordinates of the circles approximating the inner and outer iris boundaries and performed a pixelwise segmentation of the iris contours, occlusions, and reflections. This dataset is claimed to be the first collection of ocular images from public websites and social media, and one of the biggest collections of manually segmented ocular images. In this paper, benchmark results using publicly available iris segmentation and recognition algorithms are also provided for reference. The dataset is expected to open a new avenue of research on iris recognition in visible wavelength in unconstrained conditions.

With this special issue, the guest editors wish to provide to the biometrics community a scientifically stimulating content, and hope that this could robustly and reliably represent a guide for the upcoming research in the field of ocular biometrics. Last but not least, they want to thank the authors of the accepted papers that with their valuable work made the collection of this issue possible, and the reviewers that helped selecting the most relevant contributions.

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