Introduction to the Special Issue on the Segmentation of Visible Wavelength Iris Images Captured At-a-distance and On-the-move

Hugo Proença and Luís A. Alexandre

I. Overview

Deployed iris recognition systems are mainly based on Daugman's pioneering approach, and have proven their effectiveness in relatively constrained scenarios: operating in the near infra-red spectrum (NIR, 700-900 nm), at close acquisition distances and with stop-and-stare interfaces. However, the human iris supports contactless data acquisition, and it can — at least theoretically — be imaged covertly. The feasibility of covert iris recognition receives increasing attention and is of particular interest for forensic and security purposes. In this scope, one possibility is the use of visible wavelength light (VW) to perform image acquisition, although the use of this type of light can severely degrade the quality of the captured data. This is mainly due to the optical properties of the two molecules that constitute the pigment of the human iris: brown-black Eumelanin (over 90%) and yellow-reddish Pheomelanin. Eumelanin has most of its radiative fluorescence under VW, which enables the capturing of a much higher level of detail, but also of many more noisy artifacts, including specular and diffuse reflections and shadows. Also, the spectral reflectance of the sclera is significantly higher in the VW than in the NIR and the spectral radiance of the iris in respect to the levels of its pigmentation varies much more significantly in the VW than in the NIR. Furthermore, traditional template- and boundary-based iris segmentation approaches will probably fail, due to difficulties in detecting edges or in fitting rigid shapes. All these reasons justify the need of specialized segmentation strategies and were the major motivations behind the NICE.I contest (http://nice1.di.ubi.pt) that gave birth to this issue of the Image and Vision Computing Journal.

II. The Noisy Iris Challenge Evaluation - Part I contest

The goal of this contest was to evaluate iris segmentation methods on noisy images that result from the acquisition in less constrained conditions and under the VW light. In opposition to previous contests, the NICE.I exclusively evaluates the iris segmentation and noise detection stages, allowing the independent evaluation of these tasks. The UBIRIS databases were used as data sources for this event. Their most fundamental characteristic is the high levels of *noise* that images contain. A subset of 500 UBIRIS.v2 images was given to participants of the NICE.I contest and used as training data for the development of the corresponding iris segmentation and noise detection proposals. The requested task was quite simple: for each input image a corresponding binary output should be built, where the pixels that belong to the iris and are noise-free should appear as black, whereas the remaining pixels should be represented by white (figure 1).

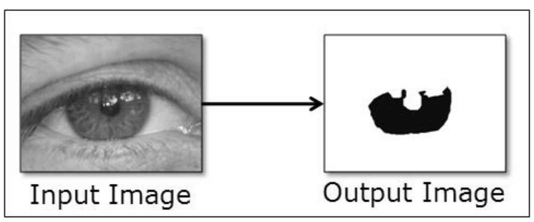

Fig. 1. NICE.I fundamental task.

Later, a disjoint test set of 500 images was used to measure the pixel-by-pixel agreement between the binary maps made by each participant and the ground-truth data, manually built by the organizers of the contest and that — *a priori* — should be accepted as the optimal segmentation. The test error rates for each submission were the average error rates for each test image. The error rates on each test image were the proportion of correctly classified pixels. The contest received a total of 97 participants from over 22 countries. The best 8 participants (those that achieved the lowest test error rates) were invited to publish their approach in this special issue, that we hope will constitute a valuable source of information for many of the researchers concerned with the segmentation of iris data acquired in far from ideal conditions.

Authors are with the Department of Computer Science, IT- Instituto de Telecomunicações, University of Beira Interior, 6200-Covilhã, Portugal {hugomcp,lfbaa}@di.ubi.pt

III. THE SPECIAL ISSUE ORGANIZATION

Dr. James Matey of the United States Naval Academy was invited to publish a paper focused on the iris recognition challenges regarding the image acquisition constraints, that also includes a general description of the currently deployed iris recognition technology. The goal was to avoid the probable repetition of state-of-the-art sections in each paper, given the narrow focus of this special issue.

TABLE I
NICE.I CLASSIFICATION.

Rank	**Authors**	**Affiliation**	**Error**
1	Tan *et* al.	Chinese Academy of Sciences	0,0131
2	Sankowski *et* al.	Technical University of Lodz	0,0162
3	Pedro Almeida	University of Beira Interior	0,0180
4	Li *et* al.	Heilongjiang University	0,0224
5	Jeong *et* al.	Dongguk University	0,0282
6	Chen *et* al.	Florida International University	0,0297
7	Scotti and Labbati	University of Milan	0,0301
8	Luengo-Oroz *et* al.	Polytechnical University of Madrid de Madrid	0,0305

The remaining papers appear ordered by their ranking in NICE.I contest (Table I). The first segmentation paper is from the Chinese Academy of Sciences (Tan *et* al.) and uses a clustering-based iris localization scheme to roughly perform iris localization followed by an integro-differential constellation approach used for fine pupillary and scleric border detection, which not only accelerates the traditional integro-differential operator but also enhances its global convergence. Finally, parametric models are learned to deal with eyelids and eyelashes. A participation from the Technical University of Lodz (Sankowski *et* al.) achieved the second best error rates. They first localize and fill reflections in a YIQ color space, and conclude that this stage has strong benefits in terms of the subsequent processing. Then, both iris boundaries are modeled by Daugman's classical integro-differential operators, followed by a parametric modeling of both eyelids. The third participation is from the University of Beira Interior (Pedro Almeida) and describes a knowledge-based approach to the iris segmentation problem. This approach is inspired in the expert system's paradigm and directly encodes a set of ”decision rules” that have high potential to evolve and constitutes an interesting alternative for this type of task. Authors from the Heilongjiang University (Li *et* al.) used the very popular method of Viola and Jones to perform fast rough eye detection and further normalized their region of interest through a K-means based technique. Having this much more normalized data the subsequent processing combines traditional iris segmentation techniques with RANSAC-like techniques. The participation from Dongguk University (Jeong *et* al.) uses an Adaboost-based technique to roughly localize the iris and compensate for errors that result from the circular modeling of both iris borders. Later, they use color information to detect reflections and propose a classification model to decide whether the eye is closed or not. The approach proposed by people of the Florida International University (Chen *et* al.) makes use of the major discriminating appearance between the sclera and the remaining parts of the eye to perform a coarse initial detection of the eye region. This region is used as ROI of further processing stages, which make their task significantly easier. Later, they propose an interesting circle correction strategy to improve the segmentation results. The participation from the University of Milan (Scotti and Labbati) significantly reduces the region of interest, starting by a coarse estimation of the iris and pupil centers. Later, in order to constraint the search for the iris boundaries exclusively within small stripes of the image, they perform iris linearization. Then, they remove eyelashes and reflections exclusively in these stripes and finally re-map the obtained boundaries into the original image. Finally, the approach from the Universidad Politécnica de Madrid (Luengo-Oroz *et* al.) proposes a very original strategy that starts by the detection of the iris center through projection techniques. This point is then used to translate a region of interest into a polar coordinate system, where morphological operators are used to perform a rough segmentation of the outer iris border. Later, the roughly segmented region returns to the Cartesian space, in order to suppress eyelids and eyebrow.

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