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Analysing Facial Regions for Face Recognition using Forensic Protocols

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Abstract. This paper focuses on the analysis of automatic facial regions extraction for face recognition applications. Traditional face recognition systems compare just full face images in order to estimate the identity, here different facial areas of face images obtained from both uncontrolled and controlled environments are extracted from a person image. In this work, we study and compare the discriminative capabilities of 15 facial regions considered in forensic practice such as full face, nose, eye, eyebrow, mouth, etc. This study is of interest to biometrics because a more robust general-purpose face recognition system can be built by fusing the similarity scores obtained from the comparison of different individual parts of the face. To analyse the discriminative power of each facial region, we have randomly defined three population subsets of 200 European subjects (male, female and mixed) from MORPH database. First facial landmarks are automatically located, checked and corrected and then 15 forensic facial regions are extracted and considered for the study. In all cases, the performance of the full face (faceISOV region) is higher than the one achieved for the rest of facial regions. It is very interesting to note that the nose region has a very significant discrimination efficiency by itself and similar to the full face performance.

Keywords: Forensic, biometrics, face recognition, facial regions, forensic casework.

1 Introduction

Automatic face recognition has been extensively researched over the past two decades. This growth is due to its easy acquisition and its important role in a growing number of application domains, including access control, video surveillance, and its wide use in government issued identity documents (e.g., passport and driving's license) [9].

An area where these kinds of systems have obtained an increased emphasis is the forensic field [7,13]. Forensic science analyses data collected by law enforcement agencies in order to prove or disapprove the guilt of a suspect with high confidence under the legal system.

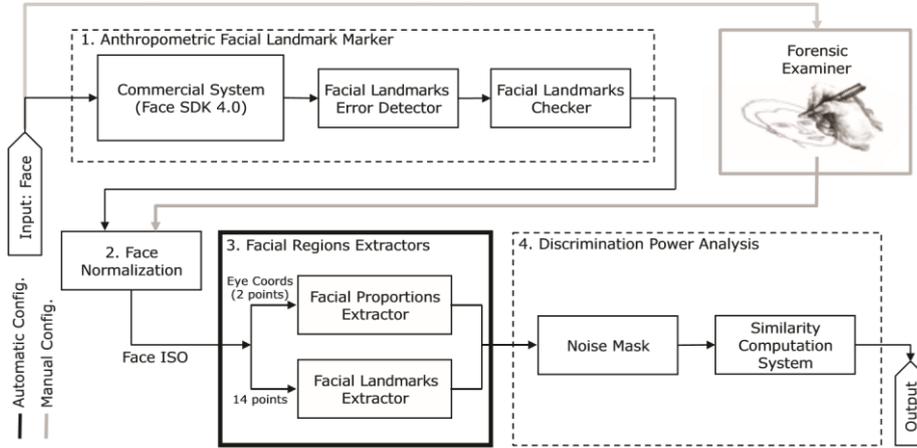


Fig.1. Experimental framework.

While DNA and fingerprint forensic identification are two of the most reliable and available identification methods in forensic science, automatic face recognition technology needs to improve the set of available tools to determine a person's identity, particularly from video surveillance imagery. Such progress for forensic face recognition is one of the goals of the FBI's Next Generation Identification program [15].

Automatic face recognition systems are generally designed to match images of full faces. However, in practise, forensic examiners focuses carry out a manual inspection of the face images, focussing their attention not only on full face but also on individual traits. They carry out an exhaustive morphological comparison, analysing the intra-variability of a face, trait by trait on nose, mouth, eyebrows, etc., even examining soft traits such as marks, moles, wrinkles, etc. On the other hand, there are several studies [22,20,12,21] based on realistic scenarios trying to understand the effect of the different variability factors in this field.

As Jain et al. describe as future work in [8,7,2], facial regions-based system for matching and retrieval would be of great value to forensic investigators.

There are some previous works where region-based face recognition is studied [19,5,11,4,1,16] but these papers do not focus their attention in the regions usually considered by forensic experts. In this work, we have extracted facial components (called from now facial regions) following forensic protocols from law enforcement agencies, allowing us to study the discriminative power of different facial regions individually. In particular we

address in this paper the problem of finding the most discriminative areas of the face for recognition.

Understanding the discrimination power of different facial regions on a wide population has some remarkable benefits, for example: *i)* allowing investigators to work only with particular regions of the face, *ii)* preventing that incomplete, noisy, and missing regions degrade the recognition

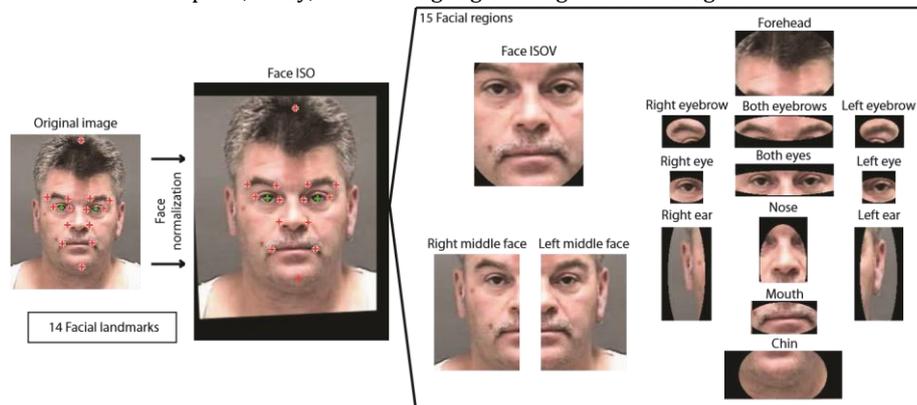


Fig.2. Facial regions extraction.

accuracy. Further, a better understanding of facial regions-based face recognition should facilitate the study of individuality models.

In summary, the main contribution of the paper is an experimental study of the discriminative power of different forensic facial regions on a wide population using forensic protocols. Additionally, we propose a novel framework for facial regions extraction useful for controlled and uncontrolled scenarios.

The rest of the paper is organized as follows. In Section 2, we provide an overview of the automatic facial region extraction procedure. Section 3 presents the analysis of the extracted facial regions defining the database used, the experimental protocol followed, the feature extraction and classification used and the experimental results achieved. We conclude in Section 4 with a discussion and summary of our work.

2 Facial Regions Extraction

This section describes the experimental framework developed to extract the different forensic facial regions analysed in this work.

The traditional inspection procedure of the law enforcement agencies carried out by forensic examiners is mainly based on manual and individual skills of the human examiners using some general image processing tools. Automatic approaches of image processing could help the examiners to reduce the human subjective decisions, reaching higher precisions. In this

sense, we have developed a useful tool able to extract different facial regions as summarized in Fig. 1.

The presented experimental framework has two different configurations in order to find the facial landmarks for extraction of the facial regions: automatic and manual. Automatic configuration uses a commercial system¹ that provides 65 facial points of which only 13 are used. These 13 facial landmarks plus a new point that indicate the top of the head (defined by us) (see Fig. 2) are used as inputs to a facial landmarks error detector developed by us based on distances, angles and symmetries between these points. This system allows us to know which facial landmark is correctly located and which of them needs to be corrected. On the other hand, the location of these facial landmarks could be done manually by a forensic examiner.

After a correct facial landmark location, faces are normalized based on the ISO standard [6] with an *Interpupillary Pixel Distance* (IPD) of 75 pixels. Therefore, facial regions can be extracted with a standard size for all faces.

In our approach we have implemented two different facial region extractors: *i*) based on human facial proportions, and *ii*) based on facial landmarks. The first one extracts the facial area of interest of the face (eyebrows, eyes, nose, mouth, etc.) using just the two eyes coordinates, following simple facial proportions rule [10,3]. The mentioned extractor would be of interest in challenging uncontrolled scenarios where landmarks are very difficult to be extracted automatically. On the other hand, the second extractor, based on facial landmarks correctly located, allows to extract the facial regions with high precision.

The experimental framework implemented extracts of 15 different facial regions as can be seen in Fig. 2. The election of these 15 regions is based on protocols from Spanish Guardia Civil [18] and NFI [14], two of the most important national forensic science laboratories in Spain and Netherlands, respectively.

3 Facial Regions Analysis

This section describes how facial regions extracted from a face are analysed in order to evaluate their discriminative power. Firstly, the database and the experimental protocol adopted for this work are presented. Then, the feature extraction and classification will be described and finally, the experimental results will be detailed.

3.1 Database

The experiments are carried out on a subset of the MORPH Non-Commercial Release database [17]. MORPH contains 55.000 frontal face images from more than 13.000 subjects, acquired from 2003 to late 2007. The distribution of ages

¹ Luxand, Inc. <http://www.luxand.com>.

ranges from 16 to 77 with an average age of 33. The average number of images per individual is 4 and the average time between pictures is 164 days, with the minimum being 1 day and the maximum being 1.681 days. The MORPH database is divided in 5 subsets named: *i*) African, *ii*) European, *iii*) Asian, *iv*) Hispanic and *v*) Other.

The subset "European" comprises 2.704 subjects (2.070 males plus 634 females) and has been selected for these experiments. Fig. 2 shows an example in our dataset together with their extracted regions.

3.2 Experimental Protocol

For the experimental work of this paper we discarded those subjects with less than three images and chose three images per subject with the smallest gap between acquisitions in order to reduce the time lapse effect. Then using this selection, three population sets were randomly chosen in order to analyse the discrimination power of each facial region on different populations: *i*) 200*female*, *ii*) 200*male*, and *iii*) 200*mix* (100 male+100 female).

Each population subset of 200 subjects with 3 face images each is then divided into: *i*) a training set comprising the first sample (enrolment template); and *ii*) an evaluation set comprised of the other two images available for each subject.

3.3 Feature Extraction and Classification

Regarding feature extraction and classification, a system based on PCASVM was adopted to compute the discrimination power between different facial regions. Different noise masks were applied to each facial region (Fig 2) (e.g. 75×101 (width × height) for nose region). PCA was applied to each facial region over the training set retaining 96% of variance. This leads to a system where the original image space (e.g. of 7.575 dimensions for nose region) is reduced to 200 dimensions. Similarity scores are computed in this PCA vector space using a SVM classifier with linear kernel.

3.4 Experimental Results

This section describes the experimental analysis of individual features of each facial region and their discrimination power (represented by EER) over the different 3 population datasets. Results are shown using ROC curves with EERs (in %).

The discrimination power of each defined forensic facial region for the three studied population datasets is presented in Fig. 3. As can be seen, doing a global analysis, faceISOV region reaches the highest performance compared to the other facial regions, followed by the nose and middle faces regions. It is worth highlighting that the faceISOV and middle faces include other facial regions considered. However, the nose region does not, hence it is important to remark that the nose region has a very high and important discrimination power with respect to the other regions of the face. Ranking the remaining facial parts regarding their discrimination power, the eye regions come next, followed by eyebrows, mouth and chin. The worst results were obtained for

the chin, which could be explained due to difficulty to locate the corresponding landmark. As it was expected, ears achieved worse results due to the common occlusion by hair and the pose. It is important to note that mouth region achieves poor performance, it could be due to variability having a not neutral expression: open, closed, smiling, etc.

As can be seen in Fig. 3 (middle and bottom), faceISOV for male and female populations has more or less the same performance, but in general discriminative results for the male population were better than female, due to less variability.

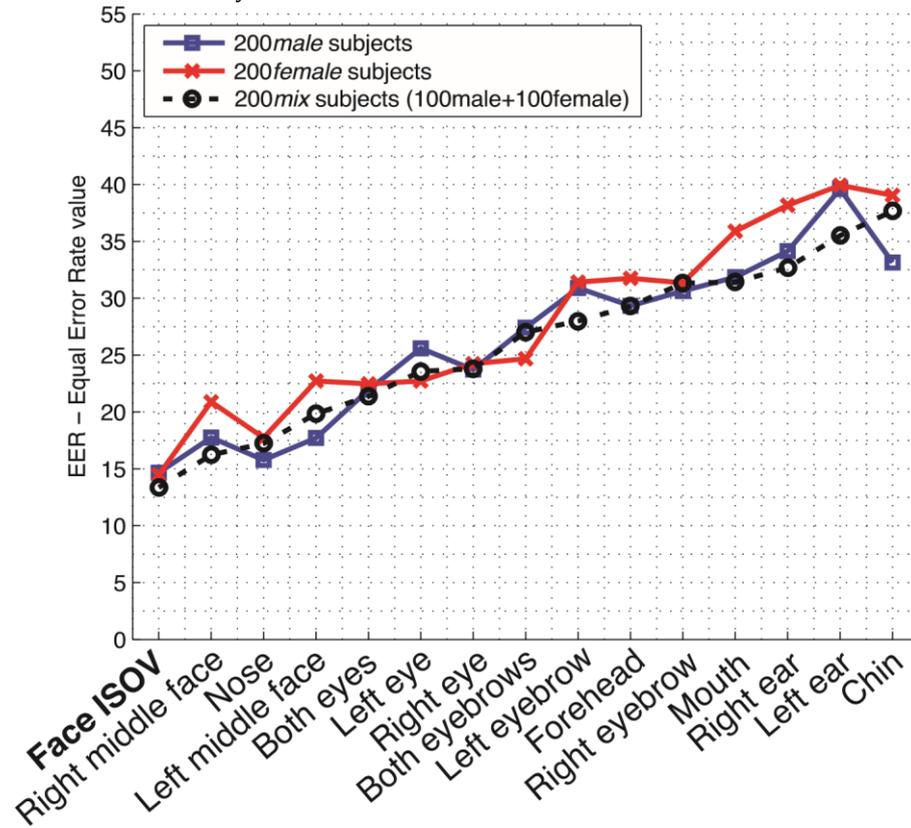


Fig.3. EER values for verification performance of different facial regions obtained for the three population sets: 200mix (dashed black line), 200female (solid red line), and 200male (solid blue line). See one example of the different regions in Fig. 2.

4 Conclusions

In the present work, an experimental framework for the extraction of different facial regions of a face has been presented and used to understand their discrimination power. The discrimination efficiency of each facial

region has been studied considering three different populations obtained from the MORPH database. In all cases, the performance of the full face named *faceISOV* region is higher than the one achieved by the rest of facial regions. In a real forensic scenario, partial faces are considered very often for recognition due to occlusions or other factors, hence this individualized study is very useful in order to give some insight into the expected degradation when working with partial faces. Furthermore, the nose region has a very significant discrimination efficiency by itself and similar to full face performance. There are notable differences between male and female performances on different facial regions and in general men achieve better discriminative results for their facial regions compared to women, most likely due to less variability of appearance. This work highlights the benefits of adequate analysis of facial regions from a face in order to better understand the facial intra-variability.

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