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Gender dictionary learning for gender classification ☆

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ABSTRACT

Human gender is one of the important demographic distinctiveness for facial image description. In this paper, a novel method is proposed for gender classification from real-world images under wide ranges of pose, expression and so on. To this end, an automatic feature extraction method is proposed by two types of features. Then, two separate dictionaries for male and female genders are defined for representing the gender in facial images. Also, two dictionary learning methods are proposed to learn the defined dictionaries in training process. Then, the Sparse Representation Classification (SRC) is adopted for classification in the testing process. Finally, a probability decision making approach is proposed to classify the gender from estimated values by SRC and proposed gender formulation. Convincing results are obtained for gender classification on three publicity databases including the FERET, LFW and Groups databases compared to several state-of-the-arts.

1. Introduction

Real-world gender classification is one of the most difficult and challenging tasks in computer vision due to unknown changes in the appearance of human faces including facial expressions, head pose changes, illumination variations, occlusion or facial makeup, etc. Automatic gender recognition has various significant applications for human-computer interaction, intelligent user interface, and so on [1–23,36,37]. Although there have been many advances in the last few years to incorporate robustness into real-world situations in gender classification approaches, it is still a challenge to attain this manner under unrestrained situations with a wide range of people in a wide age and race. Available gender classification methods can be mostly categorized into two separate types based on the type of the facial images as follows:

(1) Controlled facial images: in this case, controlled facial images in neutral expression and without any pose, illumination and so on are used for gender classification. In this context, many attempts were made to classify gender in the controlled database such as the FERET database [3,4,7,9,11,14,15,17,18]. A main problem of these studies is that face images acquired under controlled conditions (e.g., the FERET database) are considered, which are usually frontal, occlusion-free, with a clean background, consistent lighting, and limited facial expressions.
(2) Real-world facial images: in this case, the real-world images are used for gender classification. Recently, many works have attempted gender classification on real-world database such as LFW and Groups databases [3,7,9,16–19]. A main problem of these studies is that a sub-set of real-world images is considered for gender classification and images that have large pose and heavy expression and so on are not considered for gender classification.

Recently, sparse coding and dictionary learning have been successfully applied to different tasks of computer vision including face recognition, image classification, etc. [24–33,38–41]. The Sparse Representation Classification (SRC) was described by Wright et al. [29] for face recognition. In the sparse representation technique, a dictionary is generated from the training images, and matching is completed by reconstructing the testing image utilizing a sparse dictionary. In the dictionary learning context, Aharon et al. [25] proposed the K-means Singular Value Decomposition (KSVD) method for designing an over complete dictionary. Also, Zhang and Li [28] proposed Discriminative KSVD (DKSVD) for performing the face recognition which is based on extending the KSVD method. Moreover, Jiang et al. [27] presented the Label Consistent KSVD (LCKSVD) for a task of recognition including face and object recognition.

In this paper, a method is proposed for gender classification. Visual illustration of the proposed system is shown in Fig. 1.

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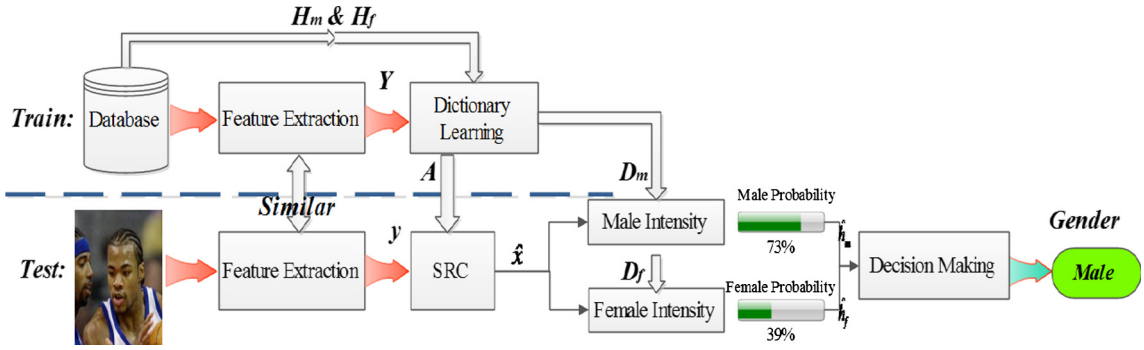

Fig. 1. Overview of proposed method for gender classification.

Accordingly, an automatic feature extraction method is proposed for gender classification. Also, two dictionaries for male and female genders are defined alongside the dictionary for features. Then, two methods are proposed to learn both male and female dictionaries, which are named Dictionary Learning for Gender Classification (DL-GC) and Separate Dictionary Learning for Gender Classification (SDL-GC). On the other hand, the SRC method is employed for classifying the test features in the testing process. Then, the probability intensity of male or female is obtained by the proposed formulation for the test image (for example in the test image in Fig. 1 the probability that the gender of this person be male is 73%, while probability that this person be female is 39%). Finally, gender is classified by the proposed decision making formulation to assign test images to a specific gender from the obtained probability of intensity. To evaluate the proposed methods, three available databases are used which include FERET [34], LFW [5] and Groups [4] databases in comparison with the state-of-the-art method for gender classification.

In this paper, the main proposed contributions are summarized as the following:

(1) Two separate dictionaries are proposed for male and female gender labeling alongside the feature dictionary based on their sparsity properties.
(2) Two methods including DL-GC and SDL-GC are proposed to learn male, female and feature dictionaries for the purpose of real-world gender classification.
(3) A probability decision making approach is proposed to infer the gender from male and female probability intensities.
(4) The proposed methods improve the gender classification rate on the FERET [34], LFW [5] and Groups [4] databases in comparison with state-of-the-art methods. Furthermore, the generalization power of the proposed method is evaluated across these two public face databases.

This paper is organized as follows: A brief review of existing related approaches for gender classification is presented in Section 2. In Section 3, the automatic feature extraction method is explained for gender classification. Section 4 describes the proposed classification method by dictionary learning. Experimental evaluations are given in Section 5 and conclusions are presented in Section 6.

2. Related works

The state-of-the-art methods are summarized in Table 1 for gender classification based on controlled and real-world images. Generally, gender classification encompasses two main steps: feature extraction and classification [1]. Hence, there are many methods to extract the features and for classification. Table 1 shows the features and classifiers of recent studies for gender classification. In the context of controlled facial images for gender classification, Moghaddam and Yang [11] utilized raw image pixels (gray level value of the pixels) of facial images as appearance-based features and achieved an accuracy of 96.6% for gender classification with nonlinear SVM on the FERET database. Also, Baluja and Rowley [14] proposed an efficient gender classification method by boosting pixel comparisons in images of the human face. On the FERET database, their method matches SVM with 500 comparison operations on $20 * 20$ pixel images. What is more, Mäkinen and Raisamo [15] systematically evaluated diverse face alignment and gender classification approaches on the FERET database. Moreover, Yang et al. [2] used the texture raw pixels for feature extraction and adopted the real Adabost classifier for gender classification on the FERET database.

Table 1
Overview of recent studies on gender classification from face images.

Methods	Feature	Classifier	Database	Real-world
Moghaddam and Yang [11]	Raw pixel	SVM	FERET	No
Baluja and Rowley [14]	Pixel comparisons	Adaboost	FERET	No
Mäkinen and Raisamo [15]	Raw pixels	SVM	FERET	No
Yang et al. [2]	Texture	Real Adaboost	FERET	No
Tapia and Pérez [17]	Fusion	SVM	FERET	No
			LFW	Yes
Shan [16]	Boosted LBP	SVM	LFW	Yes
Gallagher and Chen [4]	Contextual Features	GML	Groups	Yes
Rai and Khanna [18]	Gabor based $(2D)^2$PCA	SVM	FERET	No
			LFW	Yes
Mery and Bowyer [7]	Random Patch	Adaptive SRC	FERET	No
			Groups	Yes
Hadid et al. [19]	LBP + LPQ + BSIF	SVM	Groups	Yes
Moeini et al. [9]	LGBP	SVM	FERET	No
			LFW	Yes
Han et al. [3]	BIF	SVM	LFW	Yes
Proposed DL-GC Method	Gray + LBP	DL + SRC	FERET	No
			LFW	Yes
			Groups	Yes
Proposed SDL-GC Method	Gray + LBP	SDL + SRC	FERET	No
			LFW	Yes
			Groups	Yes

In the context of real-world facial images for gender classification, Tapia and Pérez [17] recently presented mutual information for the feature selection method and feature fusion to develop gender classification from facial images. They achieved promising results on LFW and FERET databases by adopting the SVM classifier for their feature fusion. Also, Shan [16] proposed gender recognition on real-world facial images. In their method, LBP was used