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Local quadruple pattern: A novel descriptor for facial image recognition and retrieval☆

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ABSTRACT

In this paper a novel hand-crafted local quadruple pattern (LQPAT) is proposed for facial image recognition and retrieval. Most of the existing hand-crafted descriptors encode only a limited number of pixels in the local neighborhood. Under unconstrained environment the performance of these descriptors tends to degrade drastically. Major problem in increasing the local neighborhood is that, it also increases the feature length of the descriptor. The proposed descriptor tries to overcome these problems by defining an efficient encoding structure with optimal feature length. The proposed descriptor encodes relations amongst the neighbors in quadruple space. Two micro patterns are computed from the local relationships to form the descriptor. The retrieval and recognition accuracies of the proposed descriptor has been compared with state of the art hand crafted descriptors on bench mark databases namely; Caltech-face, LFW, Color-FERET, and CASIA-face-v5. Result analysis shows that the proposed descriptor performs well under uncontrolled variations.

1. Introduction

The feature description using hand-crafted descriptors has gained more attention in the recent past due to its capability to encode individual images without any supervised learning. Such descriptors have been proposed to encode more pixels in the local neighborhood to enhance recognition and retrieval accuracies under varying pose, illumination, expression and background. The fundamental requirement of any descriptor is that, it should increase the inter class dissimilarity and decrease the intra class dissimilarity. Primary objective of the descriptors such as; Eigen-face [1], Fisher-face [1], variations of PCA [2], and Linear Discriminant Analysis (LDA) [3] is to identify the feature points of the facial images taken under constrained environment. Two dimensional and Two Directional Random Projection has been used in [4] to reduce the dimensionality of the feature matrix of an image. The major advantage of this method is that, it removes the problem of singularity, SSS (small sample size) and over-fitting [4]. DWDPA [5,6] is a unique feature description technique, which increases the discrimination power by weighting the dominant selected DCT coefficients [5,6]. Similar strategy can be adopted with spatial domain image description by computing the histogram and determining the dominant features and weighting them to improve the discriminating power.

Convolutional Neural Network (CNN) has been used to extract features from facial images by training the CNN with relevant datasets [7,8]. These learning based descriptors require large training datasets to achieve optimal recognition accuracy. These descriptors are generally application specific due to the biasness towards the training databases [9,10]. The proposed

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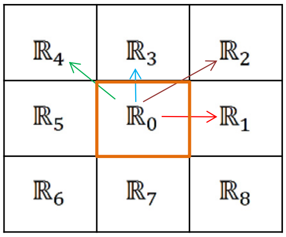

Fig. 1. Template of the LBP operator.

descriptor belongs to the class of hand-crafted descriptors, which captures the core information from the inherent pixel relations. It does not require any learning (training) mechanism to represent images (single or multiple) of a given class. Apart from this, the characteristic of the proposed descriptor is very much different from VGG face recognition model that make use of Convolutional Neural Networks (CNNs) to extract the features from an image.

One of the earliest descriptor defining the relationships in the local neighborhood is Local Binary Pattern (LBP) [11]. Eight neighbors of the reference pixels are encoded to generate the binary pattern. Centre Symmetric Local Binary Pattern (CSLBP) [12] has been derived from LBP to achieve improvements in region based image matching and length. Illumination variation is another fundamental problem in face recognition addressed through Centre Symmetric Local Ternary Pattern (CSLTP) [13]. It is a gradient based local descriptor, which works well in controlled illumination variation. Most recently Multi-Block Local Binary Pattern (MB-LBP) has been used detect pedestrians [14]. Region wise averages used to define local descriptor such as Semi Local Binary Pattern (SLBP) [15], to improve the recognition and retrieval accuracies under scale, noise and illumination variations.

There is another class of descriptors defined in the higher order derivative space. Local Directional Gradient Pattern (LDGP) [16] is one of the most recent higher order descriptor, which shows improvements over Local Derivative Pattern (LDP) [17], and Local Vector Pattern (LVP) [18] with respect to time and achieves comparable recognition rates. The proposed descriptor is a region based descriptor, which captures distinctive information in the larger region with optimal feature length and improved recognition and retrieval accuracies.

The organization of the rest of the paper is as follows. Some of the similar descriptors are elaborated in Section 2. Section 3 elaborates the motivation and proposition of the descriptor. Various experiments have been performed and the obtained results are compared with the state of the art descriptors in Section 4. The work reported through this paper is concluded in Section 5.

2. Overview of similar descriptors

In this section we give a small overview of the most closely related descriptors.

2.1. LBP

One of the most commonly used descriptors; local binary pattern (LBP) [11] captures the relationship amongst the pixels in the local neighborhood of the reference pixel. Fig. 1. shows the template of the operator. Centre pixel $\mathbb{R}_0$ is the reference pixel and remaining eight pixels $\mathbb{R}_1..\mathbb{R}_8$ are the neighboring pixels surrounding the reference pixel.

LBP is defined as a binary string generated from the encoding function B(.).

$$\mathrm{LBP}(\mathbb{R}_0) = \{\mathrm{B}(\mathrm{I}(\mathbb{R}_0), \mathrm{I}(\mathbb{R}_1)),\ \mathrm{B}(\mathrm{I}(\mathbb{R}_0), \mathrm{I}(\mathbb{R}_2))..\mathrm{B}(\mathrm{I}(\mathbb{R}_0), \mathrm{I}(\mathbb{R}_n))\}|_{n=8} \tag{1}$$

where $\mathbb{R}_0$ is the reference point (pixel) in the image and $\mathrm{I}(\mathbb{R}_0)$ returns the intensity of the pixel. B(.) is the encoding function defined as

$$\mathrm{B}(\mathrm{I}(\mathbb{R}_0), \mathrm{I}(\mathbb{R}_n)) = \begin{cases} 1 \ if \ I(\mathbb{R}_n) - I(\mathbb{R}_0) > T \\ 0 \ if \ I(\mathbb{R}_n) - I(\mathbb{R}_0) \le T \end{cases} \tag{2}$$

where T is the threshold.

Although the LBP is a rotation invariant descriptor, but fails while tested on complex facial datasets (i.e. sever changes in illumination, pose, light, scale, and expression etc.).

2.2. CSLBP

The structure of CSLBP [12] is such that it requires only 4 bits to encode the local neighborhood. The length of this local descriptor is only 4 bits long and encodes only 8 pixels. The CSLBP is defined using the template shown in Fig. 1. as follows

$$CSLBP(\mathbb{R}_0) = \{\mathrm{B}(I(\mathbb{R}_1), I(\mathbb{R}_5)),\ \mathrm{B}(I(\mathbb{R}_2), I(\mathbb{R}_6)),\ \mathrm{B}(I(\mathbb{R}_3), I(\mathbb{R}_7)),\ \mathrm{B}(I(\mathbb{R}_4), I(\mathbb{R}_8))\} \tag{3}$$

CSLBP generates the binary code using the same encoding function defined in (2).

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