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Gender and texture classification: A comparative analysis using 13 variants of local binary patterns ☆

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ABSTRACT

Among very popular local image descriptors which has shown interesting results in extracting soft facial biometric traits is the local binary patterns (LBP). LBP is a gray-scale invariant texture operator which labels the pixels of an image by thresholding the neighborhood of each pixel with the value of the center pixel and considers the result as a binary number. LBP labels can be regarded as local primitives such as curved edges, spots, flat areas etc. These labels or their statistics, most commonly the histogram, can then be used for further image analysis. Due to its discriminative power and computational simplicity, the LBP methodology has already attained an established position in computer vision. LBP is also very flexible: it can be easily adapted to different types of problems and used together with other image descriptors. Since its introduction, LBP has inspired plenty of new methods, thus revealing that texture based region descriptors can be very efficient in representing different images. Nowadays, many LBP variants can be found in the literature. This article reviews 13 variants and provides a comparative analysis on two different problems (gender and texture classification) using benchmark databases. The experiments show that basic LBP provides good results and generalizes well to different problems and hence can be a good starting point when trying to find an optimal variant for a given application. The best results are obtained with BSIF (binarized statistical image features) but at the cost of higher computational time compared to basic LBP. Furthermore, experiments on combining three best performing descriptors are conducted, pointing out useful insight into their complementarity.

1. Introduction

Undeniably, a significant number of soft biometric traits can be extracted from face images and facial movements. This generally includes gender recognition (i.e. man vs. woman), age categorization (e.g. child, youth, adult, middle-age and elderly) and ethnicity classification (e.g. Asian, Caucasian and African). These are often referred to as demographic traits and are very useful for more affective human–computer interaction (HCI) and smart environments in which the systems should adapt to the users whose behaviors and preferences are not only different at different ages but also specific to a given ethnicity and/or gender. Automatic demographic classification is also useful in many other applications such as content-based image and video retrieval, restricting access to certain areas based on gender and/or age, enhancing the performance of biometric identification systems, collecting demographic information in public places, counting the number of women entering a retail store and so on. Other soft biometric traits that can be extracted from face images include kinship information (i.e. verifying whether two persons are from the same family or not) and skin/eye color.

Among very popular local image descriptors which has shown interesting results in extracting soft facial biometric traits is the local binary patterns (LBP) [2,10,21,23]. LBP can be seen as statistics of labels computed in the local pixel neighborhoods. The LBP method describes each pixel's neighborhood by a binary code which is obtained by first convolving the image with a predefined set of linear filters and then binarizing the filter responses. The bits in the code string correspond to binarized responses of different filters. The LBP-like methods showed very good results in different computer vision tasks, including nontraditional texture problems such as face recognition, gender classification, age estimation and motion analysis [10,11,23].

The LBP method can be seen as a unifying approach to the traditionally divergent statistical and structural models of texture analysis.

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0167-8655/

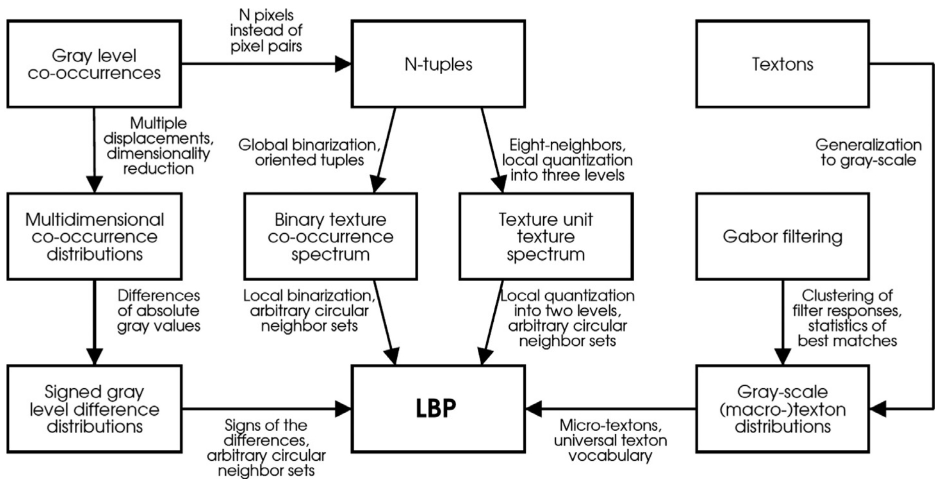

Fig. 1. Relation of LBP to some earlier texture methods [18].

Perhaps the most important property of the LBP operator in real-world applications is its invariance against monotonic gray level changes caused, for example, by illumination variations. Another equally important property is its computational simplicity, which makes it possible to analyze images in challenging real-time settings. Furthermore, LBP is also very flexible: it can be easily adapted to different types of problems and also used together with other image descriptors. The LBP is related to many well-known texture analysis operators as illustrated in Fig. 1 [18]. The arrows represent the relations between different methods, and the texts beside the arrows summarize the main differences between them. As shown in [3], local binary patterns can also be seen as a combination of local derivative filter operators whose outputs are quantized by thresholding.

Face analysis is perhaps the most fascinating application of LBP [10]. While texture features have been successfully used in various computer vision applications, only relatively few works have considered them in facial image analysis before the introduction of the LBP based face representations in 2004 [1]. Since then, the methodology has inspired plenty of new methods in face analysis. For instance, it has been successfully applied to face detection [8], face recognition [2], facial expression recognition [24], gender and age classification [28] and head pose estimation [17].

Nowadays, several variants of local binary patterns can be found in the literature. For a comprehensive bibliography of LBP-related research and links to many papers, see http://www.cse.oulu.fi/MVG/LBPBibliography. This article presents some recent and popular variants, and provides an experimental analysis comparing the performance of 13 different methods applied to two research problems namely face-based gender recognition and texture classification. Future directions are also discussed. The experimental results indicate that basic LBP still provides good results and generalizes well to different problems, hence suggesting that it can be a good starting point when trying to find an optimal variant for a given application. The best results are obtained with BSIF (binarized statistical image features) [13] but at the cost of higher computational time compared to basic LBP. Furthermore, experiments on combining three best performing descriptors are conducted, pointing out useful insight into their complementarity.

The preliminary results behind this work comparing the performance of three descriptors (LBP, BSIF and LPQ) were published as a short conference paper in [9]. We provide in this extended article a thorough investigation and new experiments comparing the performance of 13 descriptors. Obviously, it would be impossible to consider all the LBP variants in the literature as more than 100 variants of LBP have been proposed. So, we have chosen a number of LBP variants mixing between popular and recent methods while selecting the variants with publicly available source code to ensure the reproducibility of the results and the variants using 2D still images (hence ignoring the methods based on 3D and video sequences). The obtained list is quite representative but not inclusive of all the LBP variants.

The rest of this paper is organized as follows. Section 2 first introduces and explains the basic form of the LBP operator. Then, some recent and popular variants of LBP are reviewed and thoroughly discussed in Section 3. Sections 4 and 5 describe the results of the experimental analysis comparing the performance of the 13 different variants of LBP on the gender and texture classification problems, respectively. Finally, directions for future work and concluding remarks are drawn in Section 7.

2. Basic local binary patterns operator

The LBP operator, introduced by Ojala et al. [21], is defined as a gray-scale invariant texture measure, derived from a general definition of texture in a local neighborhood. It is a powerful means of texture description and among its properties in real-world applications are its discriminative power, computational simplicity and tolerance against monotonic gray-scale changes. The original LBP operator forms labels for the image pixels by thresholding the 3×3 neighborhood of each pixel with the center value and considering the result as a binary number. Fig. 2 shows an example of an LBP calculation. The histogram of these $2^8 = 256$ different labels can then be used as a texture descriptor for further analysis (e.g. classification).

The LBP operator has been extended to use neighborhoods of different sizes. Using a circular neighborhood and bilinearly interpolating values at non-integer pixel coordinates allow any radius and number of pixels in the neighborhood. The notation (P, R) is generally used for pixel neighborhoods to refer to P sampling points on a circle of radius R. The calculation of the LBP codes can be easily done in a single scan through the image. The value of the LBP code of a pixel (x_c, y_c) is

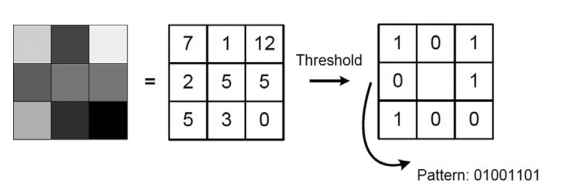

Fig. 2. The basic LBP operator.