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Image quantization as a dimensionality reduction procedure in color and texture feature extraction

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ABSTRACT

The image-based visual recognition pipeline includes a step that converts color images into images with a single channel, obtaining a color-quantized image that can be processed by feature extraction methods. In this paper we explore this step in order to produce compact features that can be used in retrieval and classification systems. We show that different quantization methods produce very different results in terms of accuracy. While compared with more complex methods, this procedure allows the feature extraction in order to achieve a significant dimensionality reduction, while preserving or improving system accuracy. The results indicate that quantization simplify images before feature extraction and dimensionality reduction, producing more compact vectors and reducing system complexity.

1. Introduction

Image recognition problems, including classification and retrieval, often present the extraction of image features as the first step in the system's pipeline. The feature extraction step is crucial since the features are going to represent images and, therefore, will be used as input for machine learning or content-based retrieval methods. Most feature extraction methods operate on a single channel 8-bit image, equivalent to a grayscale image. Even color feature extraction methods are often applied in 8-bit images, instead of using the original color spaces [1,2]. It is important to note, however, that these gray levels are actually RGB colors mapped to a lower range of values. For this reason we will refer to color as an 8-bit integer that is mapped from RGB to an 0–255 interval.

In the extraction step, one needs to choose from a wide variety of methods that will work well in some situations, while fail in others [3]. For instance, color feature extractors often used in the literature are the color coherence vectors (CCV) [4], the border/interior classification (BIC) [5] and the color correlograms [6]; while the texture extraction methods often used are the Haralick descriptors [7] and the local binary patterns (LBP) [8]. Each one can produce very different results, depending on the application.

After extracting features it is convenient to obtain a smaller feature space since most learning and retrieval methods have computational complexity proportional to the number of examples (in our context, images) and the number of dimensions. A high dimensional space can also hamper the classification accuracy due to the curse of dimensionality. The problem of dimensionality reduction, using feature selection and/or space transformation, is often addressed using methods such as Principal Component Analysis (PCA) [9] and Wrappers, which can also be combined with more sophisticated methods [10–12], and used in different applications [13,14]. In the literature we also find manifold learning methods, such as the Isometric Mapping (ISOMAP) and Locality Preserving Projection (LPP) [15], which often construct adjacency graphs in order to capture the nonlinear information of original data [2]. Another possible approach is to select subsets of descriptors that best suit each problem [16,17], but even descriptor selection methods are still application dependent and an open research problem. Thus, although these methods overcome issues of simpler and linear methods, their running time is higher.

A study comparing dimensionality reduction methods for image retrieval showed that linear methods are faster and, on average, slightly decrease the accuracy of the original set of features [2]. The PCA method was found to be the best linear method, while LPP was highlighted as the method with the best precision/complexity ratio, specially for nonlinear spaces. On the other hand, the same study pointed out that manifold methods (such as the LPP) can be unstable and need parameter tuning, but maintain the accuracy of the original feature set.

Instead of focusing on complex methods, in order to transform the feature space or select a subspace, we propose to reduce the complexity of the problem at the beginning of the process of image recognition, by using a quantization procedure before the

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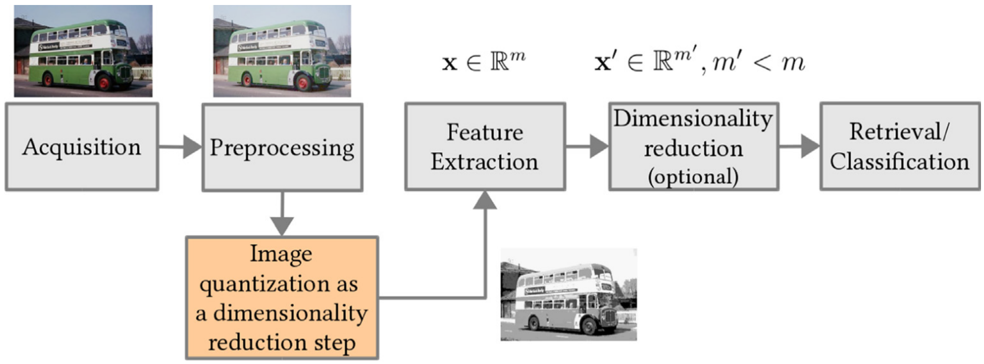

Fig. 1. Pipeline of methods used in this study. In summary, it investigates the quantization step in order to reduce both the complexity of the system and the dimensionality of the resulting feature vector $\mathbf{x}$. We also evaluated the impact of LPP for dimensionality reduction.

feature extraction (see Fig. 1 for a diagram of the proposed method). Although quantization is commonly a part of the pipeline of image classification and retrieval, it is uncommon to find studies that describe the quantization method and its parameters. When neglecting the quantization step, one can lose an important opportunity of reducing the dimensionality and/or the running time (depending on the features and methods involved).

Our hypothesis is that using a reduced number of colors with a proper quantization method will significantly reduce the dimensionality, while improving or maintaining the accuracy of a classification system. More specifically, we claim that it is possible to encode the color information using less than 8 bits to extract several features with reduced dimensionality. This procedure is simple and has potential to improve speed and reduce memory consumption, depending on the methods involved, on the following steps: feature extraction, feature selection and recognition. Also, we investigate several quantization methods, showing that some methods can improve even the final accuracy. Finally, some intuition about the effect of quantization in others feature extraction scenarios is discussed.

1.1. Related work and contribution

Only a few image-based visual recognition studies report the method used to obtain the intensity image before feature extraction. However, it is known that the choice of the color-to-grayscale method can have a significant impact on image recognition [1]. Kanan and Cottrell [1] showed that color-to-grayscale methods yield different results, producing images that can hinder even robust methods, such as SURF (Speeded Up Robust Features) and SIFT (Scale Invariable Feature Transformation). Reducing the image color complexity is also explored in [18–20], by using a restoration or spatial filtering to improve image segmentation results. In addition, according to [21,22], reducing the number of colors in the feature vector does not severely impact the accuracy of image classification. While Kanan and Cotrell [1] evaluates conversion methods (except for the most significant bit method), Ponti and Escobar [21] extended the most significant bit method without a deep investigation on the quantization parameter for different conversion methods. This gap motivated our investigation.

We investigate different quantization methods using the guidelines of [1], that pointed the methods Luminance', Intensity' and Gleam[1] to be the best among standard conversion methods. We also included in the experiments a bitwise quantization, that was originally proposed in [23] for producing 6-bit images, and then extended in [21] to allow the user to select the number of bits to be used.

[1] Luminance' and Intensity' are gamma-corrected versions of the original Luminance and Intensity methods.

The main contribution of this paper is to demonstrate that it is possible to obtain compact and effective feature vectors, by extracting features from images with reduced pixel depth (i.e. palette of intensity levels) at a low computational cost. In addition, since quantization is one of the first steps in the image recognition pipeline, we show how the feature extraction and dimensionality reduction are affected by different quantization methods. Therefore, compact descriptors can be obtained by extracting features from simpler images (in the sense of intensity level possibilities), speeding-up all further processes in classification and retrieval pipeline.

Our findings provide an addition – or an alternative – to feature selection, by using image quantization methods. Due to limiting the number of colors in the original image, the amount of possible features to be extracted is reduced, specially color ones. Texture feature extraction is also facilitated, since it often computes patterns and uses memory proportional to the number of gray levels/colors [7]. Consequently, when using color descriptors there will be a significant reduction of the feature vector size, while using texture descriptors can reduce the running time.

2. Technical background

2.1. Image feature extractors

Previous studies showed that there is no clear guideline to choose a single extraction method [3]. Therefore one option is to perform dimensionality reduction after many image features are extracted, in order to obtain a more suitable set of features. To study the impact of using different quantization parameters and several features, we choose four color descriptors and a texture descriptor based on co-occurrence matrices [7]. These descriptors were chosen using the results of a previous work by Penatti et al. [3].

All images, originally in the RGB color space, were converted to a single channel image with C intensity levels, as described in Section 3. Since the levels are values mapped from color, we will also refer them as colors, even though their visual representation are gray levels. After preprocessing the images, the following methods were used to extract features:

Global Color Histogram (GCH) [24]: This descriptor calculates a global histogram $h[.]$, where each value $h[j]$ represents the frequency of some level j in the image. Consequently, it generates a compact representation of the color information, with a C-dimensional feature vector.

Color Coherence Vectors (CCV) [4]: Is a method designed to capture information about how colors are organized in connected regions. It classifies each region as coherent or incoherent based on the area, i.e., whether or not it is part of a large similarly-colored region. Then, it produces two coherence vectors, one with coherent and the second