

# Natural Image Statistics with Low-Level Hierarchical Segmentation in Content based Image Classification



## Engineering

**KEYWORDS:** Natural image statistics, photometric scale, discrete wavelet transform, probability density function, image classification.

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### ABSTRACT

This paper aims at providing the statistics of the natural images. The properties being considered include the geometric, photometric and topological characteristics of natural images. The image is segmented using a low-level hierarchical multiscale segmentation algorithm. The algorithm provides different regions of the image which are arranged in a tree structure called segmentation tree. The geometric, photometric and topological characteristics of the regions of natural images are studied to represent the statistics of region properties. Along with the statistical properties some features like color, texture, edges and wavelet information are taken into consideration using a discrete wavelet transform. These statistical features are used to model a dataset of natural images by a probability density function. The model then used to train the dataset and finally for image classification.

### I. INTRODUCTION

A natural image is a collection of pixels arranged in a matrix form. Each image can be characterized by its geometric, photometric and topological properties. These properties are used to represent the statistics of natural images. Natural images can be defined as a set of images with similar statistical structure to which the visual system has adapted to [10]. Natural image statistics are used to develop models to be applied in computer vision and image enhancement applications.

The study of natural image statistics has wide variety of application in the field of image processing. Most of the image processing applications are meant for vision enhancement and feature extraction. Natural image statistics are applied either to derive properties, laws, etc. related to images or to develop models for image properties.

This paper is aimed at obtaining the statistics of some of the geometric and photometric properties of natural images. In order to study the properties, the original image is subject to segmentation. A segmentation algorithm called low-level hierarchical multiscale segmentation algorithm [3] is used for this purpose. It focuses on the regions rather than the pixel configuration of the image. This algorithm is used because it does not require any prior information on the region shapes or sizes and user supplied parameters. Also, it provides a better performance compared to other low level segmentation algorithms.

Next, to study the statistics, region properties are taken into account. The statistics represents the behavior of the natural images. In addition to the statistical properties some features like color, texture, moments and wavelet are compared to model the images with a probability density function. Discrete Wavelet Transform (DWT) is used for this purpose. Finally, the model is used in a high level application to classify the images in the dataset.

### II. RELATED WORK

In this section, we describe some of the previous works done on natural image statistics and its applications. Natural image statistics have gained a great importance in recent years. The study has led to various applications in image processing like denoising [14], [18], inpainting [14], scene categorization [17], [4], object detection [16], texture synthesis [9] and many others [15].

Emre Akbas and Narendra Ahuja [1] studied natural image statistics as a probabilistic model considering the low-level features of image regions. Most of the previous works in this category are based on the analysis of pixels or patches of images. Alvarez et al. [5] used an intensity based segmentation to represent the size distribution of image

regions. A low complexity orientation detection algorithm proposed by V.V. Appia and R. Narasimha [6] determined that the most stable orientations of an image is in multiples of 90. Carreira and Sminchisescu [7] analyzed figure ground segmentation based on mid-level properties of image regions. Statistics of high level and human segmentations of images have been investigated [11]. A model for denoising and inpainting applications, field of experts (FoE) was proposed by Roth and Black [13]. F Perronnin et al. presented fisher kernels for image categorization [12].

### III. SEGMENTATION AND STATISTICS

This section describes the segmentation of images and the statistics of the properties of image regions. Here, some of the geometric and photometric properties are taken into account.

#### A. Segmentation Tree Representation

The original natural image is selected and converted to a grayscale image. A grayscale image is a digital representation in which the intensity values of pixels are in the range 0 to 255. A low-level multiscale segmentation algorithm [3] is applied on the image. The algorithm produces regions of the image in a hierarchical manner. These detected regions are organized in a tree structure called the segmentation tree [1]. The root node of the tree is the original image and children nodes correspond to the contained regions. A segmentation tree can be shown in Fig. 1. The tree is build bottom up by considering the interactions among the pixels. Each region exhibits some interior homogeneity among pixels and certain degree of contrast between the adjacent regions [1]. This concept is exploited to detect regions of an image. The hierarchical representation shows the relationship between the regions.

#### B. Properties and their Statistics

The properties of natural images can be divided into two:

- **Intrinsic properties:** Properties specific to the regions itself. They can be area, perimeter, orientation etc.
- **Relative properties:** Properties of image regions that shows the relationship with its surrounding regions. The location of center of mass w.r.t. parent is an example.

In this paper, natural images belonging to a particular dataset of 1000 images is analyzed. The region properties of different images are studied from the segmentation. Some of the findings are given below.

- **Location of Center of Mass**

The regions of different natural images have been considered. By analyzing different image regions it has been found that most of the regions are

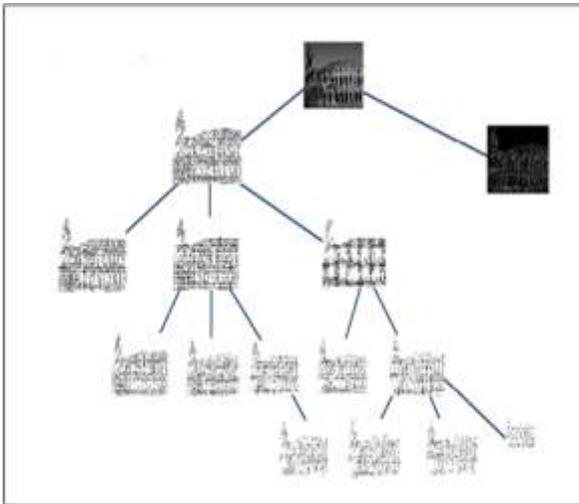


Fig.1 Segmentation tree of a natural image

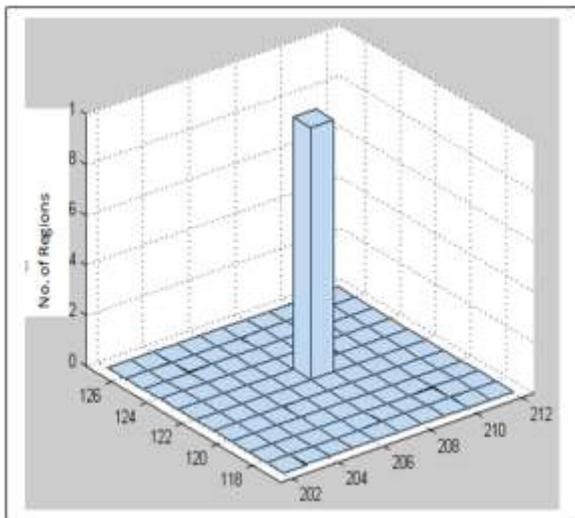


Fig. 2. Two Dimensional histogram of regions around the center of mass

concentrated near the center of mass region rather than the edges. Center of mass is the area of an image where the distributed mass sums to zero or position where the image is balanced. The distribution of regions versus the xy-coordinates is shown in Fig.2.

• **Area of Regions**

The statistics of number of regions versus region area shows that most of the regions have small area. It is shown in Fig.3.

• **Photometric scale versus number of regions**

Photometric scale is the measure of contrast between different regions. It can be represented by the intensity variations among pixels. It has been found that the photometric scale versus the number of regions follows an exponential distribution, i.e. as the contrast level is increased the number of regions decreases. It can be shown in Fig.4. The photometric scale is measured for both positive and negative values.

**C. Feature Extraction**

In addition to the above statistics, some features such as color, texture, edge characteristics, moments and wavelet representation of the image regions are extracted. These features provide a better result for image classification given in the next section.

• **Color**

The RGB image is quantized into HSV image. Columns of RGB colormap represent intensities of red, green and blue whereas HSV colormap gives hue, saturation and value. The image is split into H, S, and V planes and quantization values are calculated.

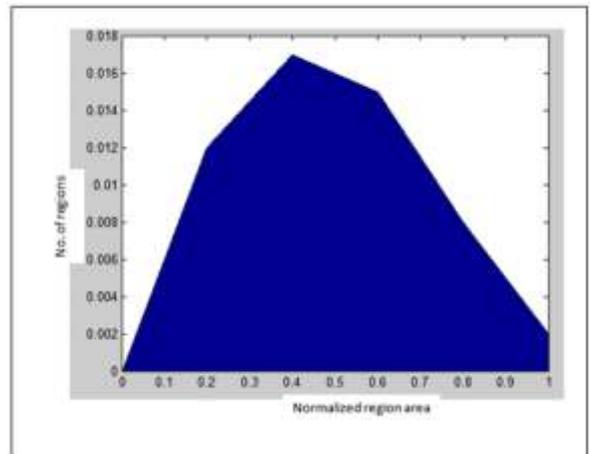


Fig.3. Normalized region area versus number of regions

• **Edges**

The edge features are used to find the pixel neighbors. Each color in the original image is mapped into a close color in an indexed image. The image is quantized into a vector format.

• **Moments**

The first two color moments i.e., mean and standard deviation, are extracted from each of the R, G, and B channels.

• **Wavelet**

A Gabor filter is used to calculate the Gabor features such as mean squared energy and mean amplitude for each scale and orientation. A Discrete Wavelet Transform is applied which provides a feature vector containing the first two moments of wavelet coefficients.

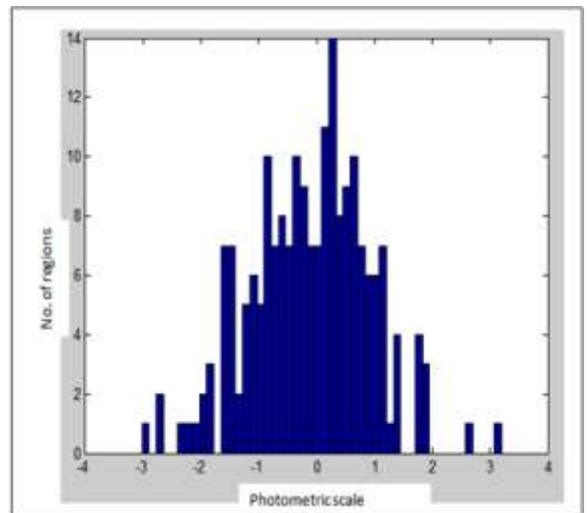


Fig.4. Photometric scale versus number of regions

**IV. IMAGE CLASSIFICATION**

The features and statistics of image regions discussed above can be utilized for a high level image processing application: image classification. For this, consider a dataset of 1000 images belonging to 10 different classes viz. , Africans, beaches, mountains, buses, monuments, dinosaurs, elephants, flowers, horses and food. The image features are extracted and then Support Vector Machines (SVM) [8] is used to classify the images.

First, assign distinct labels to each category of classes. Next, split the dataset into training and testing datasets. Each of them contains 500 images. A one-to-one comparison is done for each of the images. SVM with kernel function maps the training data into kernel space. Test the dataset to classify the images in each row using information from trained data of SVM. Classify the images by comparing the labels of each class. The relationship between pixels is calculated by Euclidean distance and sorted according to the increasing distance. A probability matrix is plotted which provides the accuracy of classification. It gives the percentage value of images belonging to a class. The result of the classification can be shown in Fig.5.

## V. CONCLUSION AND FUTURE WORK

We have presented natural image statistics based on a low-level multiscale segmentation. The segmentation resulted in a hierarchical tree structure of image regions. The detected regions were used to study some geometric and photometric properties of natural images. We confirm the finding that the photometric scale versus the number of regions follows an exponential distribution. Statistics of the selected properties were presented. Features such as color, texture, moment and wavelet were extracted to represent the image characteristics. We have used the statistics and other features of image regions and applied them on a high level application of computer vision i.e., image classification.



**Fig.5. Image classification. It shows the images from five different classes of the dataset.**

The classification was applied on a dataset of 1000 images with 10 classes. The classification of images is accurate. We also presented a probability matrix that shows the percentage of occurrence of each class of natural images.

This research work can be extended to different datasets with more number of classes with a different discriminative classifier.

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