

Image Segmentation Using Semi-Supervised k-Means

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ABSTRACT

Extracting the region of interest is a very challenging task in Image Processing. Image segmentation is an important technique for image processing which aims at partitioning the image into different homogeneous regions or clusters. Lots of general-purpose techniques and algorithms have been developed and widely applied in various application areas. In this paper, a Semi-Supervised k-means segmentation method is proposed. First, an image thresholding has been performed to get the optimal threshold value of the image which categorizes the image in to two main parts. This optimal threshold value is then used to label the objects in the image to be initialized as initial cluster centroids in Semi-Supervised k-means algorithm. At the end of clustering, a mask of labeled parts of image has been created. To evaluate the results and compare them with k-means simple algorithm, PSNR criteria of the images are used. Evaluations show that this method has better accuracy in comparison with the unsupervised k-means.

Keywords: optimal thresholding, k-means, semi-supervised k-means, PSNR

1. INTRODUCTION

Image segmentation is an important technique for image processing which aims at partitioning the image into different homogeneous regions or clusters. Most computer vision and image analysis problems require a segmentation stage in order to detect objects or divide the image into regions which can be considered homogeneous according to a given criterion, such as color, motion, texture, etc. Clustering is the search for distinct groups in the feature space. It is expected that these groups have different structures and that can be clearly differentiated. The clustering task separates the data into number of partitions, which are volumes in the n-dimensional feature space. These partitions define a hard limit between the different groups and depend on the functions used to model the data distribution.

The goal of the semi-supervised image segmentation is to obtain the segmentation from a partially labeled image. Sankari et al [1] presented a segmentation algorithm based on Semi-Supervised clustering which integrates limited human assistance. Instead of mouse clicks [2], the user selected some window area by mouse, the selected object inside the window used to be segmented and displayed. Paiva et al [3] proposed Semi-Supervised image segmentation based on novelty selection method as the preprocessing step to reduce the number of data points while retaining the fundamental structure of the data. They took advantage of the fact that neighboring points in the features space convey approximately the same information. Sun et al [4] proposed a region based Semi-Supervised clustering image segmentation method. They assumed the adjacent or nearby regions in labeled image belong to the same cluster. They used labeled and assigned unlabeled data with different weights during the iterative clustering process. They also introduced a penalty function when labeled data were incorrectly segmented. Wang et al [5] proposed a Semi-Supervised image segmentation method based on Level Set and the interactive information between user and system as the prior knowledge. They introduced a model which was based on active contour without edge and prior shape. As the reason of imprecise prior shape user inputs, the weighted area algorithm based on the gradient and Laplace was introduced.

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In this paper, it is taken advantage of the Semi-Supervised k-means algorithm for image segmentation based on optimal thresholding technique to initialize centroids of Semi-Supervised k-means. At the end, the experimental results on BEREKELY image Dataset are demonstrated and compared by means of PSNR criteria to evaluate the quality of the proposed method. Results show the efficiency of the proposed method.

The rest of this paper is as follows. In part 3, the block diagram of the proposed method is shown and the optimal thresholding and Semi-Supervised k-means algorithm are depicted in parts 3.1 and 3.2, respectively. Then the experimental results and conclusion parts are illustrated in the end parts.

2. IMAGE SEGMENTATION AND K-MEANS CLUSTERING ALGORITHMS

K-Means algorithm is an unsupervised clustering algorithm that classifies the input datapoints into multiple classes based on their inherent distance from each other.

The algorithm assumes that the data features form a vector space and tries to find natural clustering in them. The points are clustered around centroids $\mu_i, \forall i = 1 \dots k$ which are obtained by minimizing the objective

$$V = \sum_{i=1}^k \sum_{x_j \in S_i} (x_j - \mu_i)^2 \quad (1)$$

where there are k clusters $S_i, i = 1, 2, \dots, k$ and μ_i is the centroid or mean point of all the points $x_j \in S_i$.

As a part of this project, an iterative version of the algorithm was implemented. The algorithm takes a 2 dimensional image as input. Various steps in the algorithm are as follows:

1. Compute the intensity distribution (also called the histogram) of the intensities.
2. Initialize the centroids with k random intensities.
3. Repeat the following steps until the cluster labels of the image do not change anymore.
4. Cluster the points based on distance of their intensities from the centroid intensities.

$$c^{(i)} := \operatorname{argmin} \|x^{(i)} - \mu_j\|^2 \quad (2)$$

5. Compute the new centroid for each of the clusters.

$$\mu_i := \frac{\sum_{i=1}^m 1\{c_{(i)} = j\} x^{(i)}}{\sum_{i=1}^m 1\{c_{(i)} = j\}} \quad (3)$$

where k is a parameter of the algorithm (the number of clusters to be found), i iterates over the all the intensities, j iterates over all the centroids and μ_i are the centroid intensities.

3. PROPOSED METHOD

The block diagram of the proposed method is shown below:

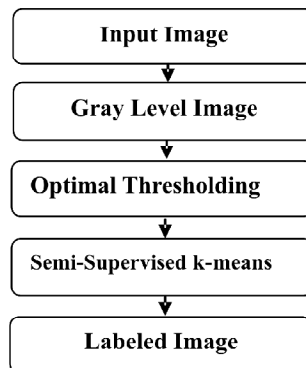


Figure 1: The block diagram of proposed method

At the beginning of the proposed method, the image is converted to the grey-level image which can facilitate the segmentation process. Then the followings steps are applied to get the labeled image as the result of the Semi-Supervised k-means algorithm.

3.1. Optimal Thresholding

The simplest thresholding methods replace in an image with a black pixel if the image intensity I_{ij} is less than some fixed constant T (that is, $I_{ij} < T$), or a white pixel if the image intensity is greater than that constant.

In this part, it is aimed to get the optimal threshold of the image which is used to create the initial labeled image as the initial centroids of k-means algorithm for prior knowledge of the labeled data. The optimal thresholding technique is based on Ridler [6] iterative proposed method and contains steps below:

Step 1: mean intensity of the image from histogram is firstly computed as the initial threshold value.

Step 2: Then the sample mean of the data is taken by the achieved threshold.

Step 3: Repeat step 2 iteratively till the condition $T(i) \neq T(i - 1)$ is confirmed.

Ridler et al. [6] proposed a method for image thresholding based on two-class Gaussian mixture models.

At iteration “ n ”, a new threshold T_n is established using the average of the foreground and background class means. Iterations terminates when the changes $|T_n - T_{n+1}|$ become sufficiently small.

$$T_{opt} = \lim_{n \rightarrow \infty} \frac{m_f(T_n) + m_b(T_n)}{2} \quad (4)$$

$$\begin{aligned} m_f(n) &= \sum_{g=0}^{T_n} gp(g), m_b(T_n) \\ &= \sum_{g=T_n+1}^G gp(g) \end{aligned}$$

Where g is the peak of the image histogram, and p is the probability density function of the image. m_f and m_b is the mean intensity of the foreground and background of the image, respectively.

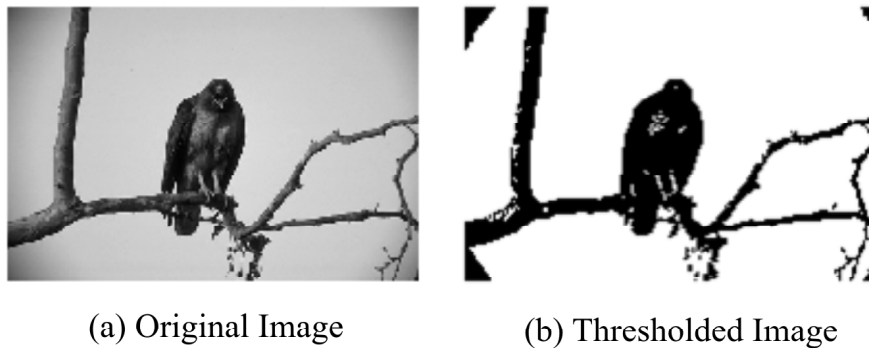


Figure 2: The result of Optimal Thresholding

3.2. Semi-supervised k-means Algorithm

K-means clustering (MacQueen, 1967) [7, 8] is a method commonly used to automatically partition a dataset into k clusters. The algorithms of k-means and Semi-Supervised k-means are presented in detail in figure.3 and figure. 4:

K-means Algorithm**Input:** a dataset $X = \{x_1, x_2, \dots, x_N\}$, number of clusters k **Output:** k-partitioning of $\{X\}_{l=1}^k$ of X

1. Select k data points as the initial cluster centers randomly $\{\mu_1, \mu_2, \dots, \mu_k\}$
2. Each data point X_i is assigned to its closest cluster center.
3. Each cluster center μ_l is clustered to be the mean of its constituent data points.
4. Repeat 2 and 3 k-means objective function is optimized

Figure 3: The K-means algorithm**Semi-Supervised K-means Algorithm****Input:** a dataset $X = \{x_1, x_2, \dots, x_N\}$, number of clusters k , a set $\cup_{l=1}^k S_l$ of labeled data**Output:** k-partitioning of $\{X\}_{l=1}^k$ of X

1. Select k data points as the initial cluster centers

$$\{\mu_1, \mu_2, \dots, \mu_k\}, \mu_l = \frac{1}{|S_l|} \sum_{x \in S_l} x, l = 1, \dots, k$$

2. Each data point X_i is assigned to its closest cluster center.
3. Each cluster center μ_l is clustered to be the mean of its constituent data points.
4. Repeat 2 and 3 k-means objective function is optimized

Figure 4: The Semi-Supervised K-means algorithm

It is well known that the most challenge of k-means algorithm is selection of the initial cluster centers. The traditional k-means algorithm randomly selects k datapoints as initial cluster centers from unlabeled dataset, which leads to the chances of it getting stuck in poor local optima. In this paper, it is taken advantage of Semi-Supervised k-means algorithm [9] which uses a set of labeled data to initialize cluster centers in the first step of k-means algorithm. Here, it is tried to create a set of labeled data by using an optimal thresholding technique to obtain the proper threshold. Then, the mean of the maximum intensity of the image histogram and this optimum threshold is used to initialize cluster centers. Other steps of the algorithm continues until its convergence.

At the end, a mask of labeled data was then obtained as the result of Semi-Supervised k-means Image Segmentation by taking advantage of the weighted centroids computed by this algorithm.

4. EXPERIMENTAL RESULTS

Peak signal to noise ratio, often abbreviated PSNR, is an engineering term for the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Because many signals have a very wide dynamic range, PSNR is usually expressed in terms of the logarithmic decibel scale. PSNR is most commonly used to measure the quality of reconstruction of lossy compression codecs. The signal in this case is the original data, and the noise is the error introduced by compression. When comparing compression codecs, PSNR is an approximation to human perception of reconstruction quality. Although a higher PSNR generally indicates that the reconstruction is of higher quality, in some cases it may not. One has to be extremely careful with the range of validity of this metric; it is only conclusively valid when it is used to compare results from the same codec and same content [10].

The proposed method has been implemented using MATLAB. The segmentation results have been shown as the following in comparison to the k-means image segmentation algorithm for some samples of images of

the BEREKELY Image Dataset. The PSNR criteria are shown of each of the algorithms. In figure 5(a) and (b) the comparison of results are shown by using two sample images of the BEREKELY image Dataset.

PSNR is the proportion between maximum attainable powers and corrupting noise that influence similarity of image pixels. The PSNR is usually used as measure of quality rebuilding of image. The signal in this case is original data and the noise is the error imported. High value of PSNR signifies the big Quality of image. It is explained via the Mean Square Error (MSE) and analogous deformity metric, the Peak Signal to Noise Ratio. Here Max is maximum pixel value of image when pixel is represented by using 8 bits per sample. This is 255 bar color image with three RGB value per pixel. The higher the PSNR values, the better the quality of image.

$$\begin{aligned} PSNR &= 10 \cdot \log_{10} \left(\frac{MAX^2 I}{MSE} \right) \\ &= 20 \cdot \log_{10} \left(\frac{MAX I}{\sqrt{MSE}} \right) \\ &= 20 \cdot \log_{10}(MAX I) - 10 \log_{10}(MSE) \end{aligned} \quad (5)$$

As it can be seen in figure 4. (a) and (b), the promising results are achieved by taking advantage of the Semi-Supervised k-means image segmentation.

5. CONCLUSION

Image segmentation is an important technique for image processing which aims at partitioning the image into different homogeneous regions or clusters. In this paper, a semi-supervised k-means segmentation method is proposed. First, an image thresholding has been performed to get the optimal threshold value of the image which categorizes the image in to two main parts. This optimal threshold value is then used to label the objects in the image to be initialized as initial cluster centroids in semi-supervised k-means algorithm. At the end of clustering, a mask of labeled parts of image has been created. To evaluate the results and compare them with k-means simple algorithm, PSNR criteria of the images is used. Evaluations show that this method has better accuracy in comparison with the unsupervised k-means.

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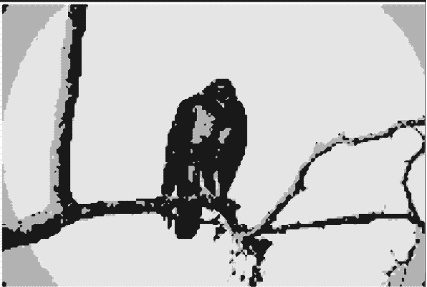



		
Original Image	Segmented Image, PSNR=3.41	RGB Labeled Image
		
Cluster 1	Cluster 2	Cluster 3
k-means		
		
Original Image	Segmented Image, PSNR=3.56	RGB Labeled Image
		
Cluster 1	Cluster 2	Cluster 3
Semi-Supervised k-means		

Figure 5 (a): Results of k-means and Semi-Supervised k-means from image sample 1 of BEREKELY Image Dataset



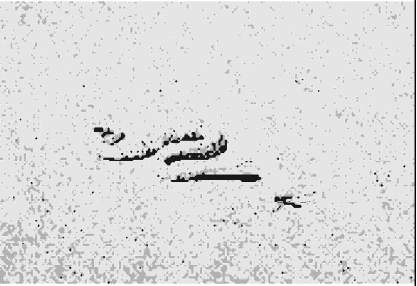
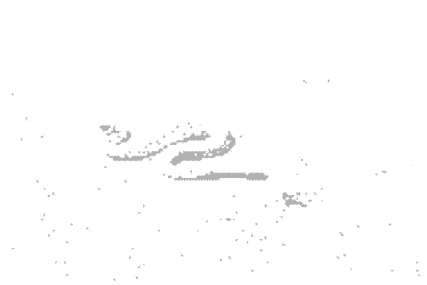
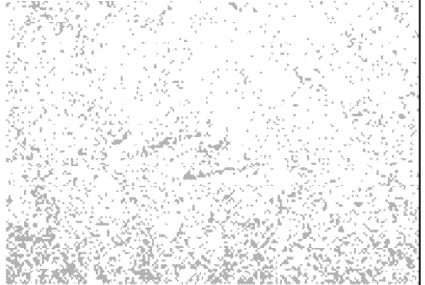



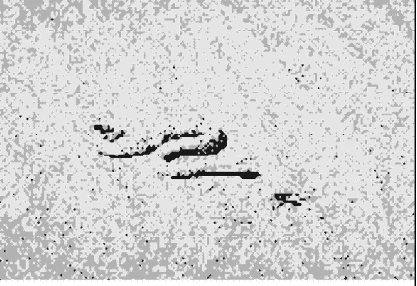



		
Original Image	Segmented Image, PSNR=5.98	RGB Labeled Image
		
Cluster 1	Cluster 2	Cluster 3
k-means		
		
Original Image	Segmented Image, PSNR=6.12	RGB Labeled Image
		
Cluster 1	Cluster 2	Cluster 3
Semi-Supervised k-means		

Figure 5 (b): Results of k-means and Semi-Supervised k-means from image sample 2 of BEREKELY Image Dataset