Towards a Faster Image Segmentation Using the K-means Algorithm on Grayscale Histogram

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ABSTRACT

The K-means is a popular clustering algorithm known for its simplicity and efficiency. However the elapsed computation time is one of its main weaknesses. In this paper, the authors use the K-means algorithm to segment grayscale images. Their aim is to reduce the computation time elapsed in the K-means algorithm by using a grayscale histogram without loss of accuracy in calculating the clusters centers. The main idea consists of calculating the histogram of the original image, applying the K-means on the histogram until the equilibrium state is reached, and computing the clusters centers then the authors use the clusters centers to run the K-means for a single iteration. Tests of accuracy and computational time are presented to show the advantages and inconveniences of the proposed method.

KEYWORDS

Computational Time, Grayscale Images, Histogram, Image Segmentation, K-Means

1. INTRODUCTION

Image segmentation is an important and difficult process in artificial vision. It aims to gather pixels having the same properties into the same segment. One way of approaching this problem is to use the well-known K-means algorithm (Arthur et al., 2006) to extract the different segments of a given image.

Given an image represented by bi-dimensional matrix, the aim is to gather each pixel into a given number of clusters (segments). The cluster is represented by one clusters center. A minimum distance (Archana et al., 2013) between all pixels belonging to the cluster and the cluster center should be reached (objective function). The process is repeated until the equilibrium state is reached (Tan et al., 2002).

This paper presents a novel and faster way to run the K-means algorithm and calculate the clusters centers on grayscale-images using a simple and intuitive idea. We propose a method to decrease the computation time of the K-means using the grayscale histogram of the input image. The grayscale histogram allows the K-means to reach the equilibrium state faster without losing accuracy of the computed clusters centers. To extract the segments of the original image, a single iteration of the K-means algorithm is applied using the already calculated clusters centers from the histogram.

This paper is organized as follows: section 2 presents the related work. Section 3 presents the developed method. In section 4 are presented the experimental results. The experiments are applied on the BSDS500 (Martin et al., 2001) benchmarks. Comparison results are presented and discussed. Finally, section 5 concludes the paper with some remarks on ways to improve the work.

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2. RELATED WORK

Many research efforts have been made to improve the K-means computation time and its convergence. Similar approaches to our proposed method have been done using the HSV color space (Tse-Wei et al., 2008; Zadeh, 2013) for grayscale and colored image, and a very fast computation time has been noticed with a good clustering efficiency. Another of the many approaches treats the change in the distance metric used between intra-clusters. The Euclidean (Danielsson & Per-Erik, 1980) distance is the more often used as in (Wang et al., 2005), the result of the clusters is spherical or ball-shaped and usually used for data in two or three dimension (Anil, 2010; Su et al., 2001) and also gives good results when the clusters are compact or outlying (Anil et al., 1999). More variations on how to calculate the distances have been developed, such as the Minkowski distance metric (Ridder, 1992; Ichino et al., 1994), which is a more general formula than the Euclidean distance metric such in (Archana, S et al., 2013; Anil, 2010; De Amorim et al., 2012). The Manhattan distance (Pieterse & Paul, 2006), a more specific formula than the Euclidian distance, can also be used as a distance metric as in (Archana, et al., 2013; Anil, 2010; Kahkashan & Sunita, 2013). The Mahalanobis distance metric (De Maesschalck et al., 2000) is also used in (Xiang et al., 2008) for data with high dimensional size. The Itakura–Saito distance (Enqvist & Karlsson, 2008) is also used in vector quantization for speech processing (Anil, 2010). All distances metrics aim to reduce the computation time of the K-means algorithm and try to make the algorithm converge faster.

Computation time of the K-means algorithm can be decreased by changing the means of calculating the clusters centers. The mean value of instances belonging to the same cluster is the more often used (Arthur et al., 2006; Archana, S et al., 2013; Anil, 2010; David, 2000). Other options include using the K-mediane (Chen, 2006; Har-Peled & Mazumdar, 2004), which employs the median to recalculate the new clusters centers. Or to use the harmonic mean (Bin et al., 1999; Bin, 2000) to recalculate the new clusters centers. Studies have been done to relax the K-means algorithm by introducing an alternative algorithm called the fuzzy C-means (Bezdek et al., 1984; Zhihui et al., 2014). The fuzzy C-means clustering algorithm (FCM) is a method based on a degree of membership to determine to which cluster each instance belongs and a parameter epsilon that represents the accepted error for convergence (Pal et al., 1995).

The K-means++ was presented in (Ackermann et al., 2010; Arthur & Vassilvitskii, 2012; Bahmani et al., 2012). This method doesn’t rely on the randomness initialization of the initial clusters centers, and uses a specific algorithm to ensure a better distribution of the first clusters centers on the data range.

Another alternative is to use a spectral method for clustering when the data input is non-linearly separable (Dhillon et al., 2004). Such algorithms have been successfully used in many applications including computer vision, but despite their empirical success, different authors still disagree on exactly which eigenvectors are used and how to derive clusters from them.

Optimization is important but quality of clustering cannot be lost in the process.

Information about the object in the image is given as input information with the dataset and the process of clustering is guided by the domain knowledge (Kiriet al., 2001). A modification of the traditional K-means is made such that the background knowledge is expressed in instance-level constraints on the clustering process.

The purpose of this paper is to propose a new approach to reduce the computation time of K-means algorithm used in image segmentation without losing segmentation precision by exploring a simple and intuitive way to use the histogram of the input image.

3. THE PROPOSED METHOD

Our method aims to segment a given image \( I_m \) into different clusters \( C_i \) using the well-known K-means algorithm. Computation time is reduced by applying the K-means algorithm on a histogram of the image instead of on the original image.
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