Survey on Image Segmentation via Clustering

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Abstract – This paper is a survey to achieve image segmentation by using different clustering techniques. The goal of image segmentation is to cluster pixels into salient image regions such as individual surfaces, objects, natural parts of objects. Clustering technique can be used for image segmentation. Clustering in image segmentation is the process of identifying groups of related images. To achieve the superpixel formation, many clustering techniques can be classified. The purpose of using clustering technique is to get proper result with high efficiency effective storage image.

Index Terms –Image segmentation, Superpixel, Region approach, Boundary approach, Clustering, Relevance feedback, Supervised clustering, Unsupervised clustering, Hierarchical, Partitional clustering, K-means clustering, Fuzzy clustering.

1. Introduction

An image is a two dimensional function that represents a measure of some characteristics such as brightness or color of a viewed scene. An image is a projection of a three dimensional scene into a two dimensional projection plane. Analog image can be mathematically represented as a continuous range of values representing position and intensity. An analog image is characterized by a physical magnitude varying continuously in space. Digital image is composed of picture elements called pixels. A pixel represents the picture element. Pixels are the smallest sample of an image. A pixel represents brightness at one point. The processing of an image by means of a computer is generally termed as digital image processing. The different elements of an image processing systems are image acquisition element, image storage devices, image processing elements and image display devices.

Digital images play an important role in daily applications such as satellite television, magnetic resonance imaging, computer tomography as well as in areas of research and technology such as geographical information systems and astronomy. Digital image processing is widely used in different fields like medicine, forensics, remote sensing, communications and automobiles. Segmented images are used routinely in a multitude of different applications, such as, analysis, treatment planning, in the robotics, localization of pathology, geology, study of anatomical structure, meteorology, computer-integrated surgery [10].

2. Segmentation

Typical computer vision applications usually require an image segmentation-preprocessing algorithm [1]. The main goal of image segmentation is domain independent partitioning of an image into a set of disjoint regions that are visually different, homogeneous and meaningful with respect to some characteristics [8]. Image segmentation is the major part in digital image processing. Image segmentation is the process of divide the images into regions. Image segmentation methods are categorized on the basis of two properties discontinuity and homogeneity. Methods based on discontinuities are called as boundary based methods and methods based on homogeneity are called Region based methods [7]. It is an important process in image processing. It is defined as the process of partitioning the digital image into different sub regions of homogeneity. The main objective of image segmentation is to cluster pixels into salient image regions.

Image segmentation can be classified into Local segmentation and Global segmentation. Local segmentation is the process of segmenting sub-images which are small windows on a whole image. Global segmentation is the process of segmenting the whole image. The number of pixels used in local segmentation is very much lower than the global segmentation. The main objective of image

segmentation is to partition an image into a meaningful region with respect to a particular application.

Image segmentation contains three approaches such as region approach, boundary approach and edge approach. In region approach, each pixel is assigned to a particular region or object. In boundary approach, the boundaries exist between the regions. In edge approach, edges are identified first and then they are linked together to form required boundaries. Region growing is an approach to image segmentation in which neighboring pixels are examined and added to a region class if no edges are detected. If adjacent regions are found then region merging algorithm is used in which weak edges are dissolved and strong edges are considered. Region growing offers several advantages over conventional segmentation techniques. This algorithm is also very stable with respect to noise. Region splitting and merging is a continuous approach after region growing. Region splitting and merging is an image segmentation technique that takes spatial information into consideration.

Image segmentation is based on two basic properties of image (i) intensity values involving discontinuity that refers to rapid or abrupt changes in intensity as edges and (ii) resemblance that refers to partitioning a digital image into regions according to some pre-defined likeness criterion [1]. Image segmentation has been approached from a wide variety of perspectives. Our summary is presented for histogram thresholding, edge based segmentation, tree or graph based approaches, region growing, clustering, probabilistic or Bayesian approaches, neural networks for segmentation and other approaches.

Image segmentation is one of the best known problems in computer vision. Graph based methods were earlier considered to be too insufficient in practice. Recent advances in technology and algorithm [22][18] have negated this assumption [5]. The segmentation is based on measurements taken from the image such as color, depth, gray level, texture. Image segmentation is an initial and vital step in a series of processes aimed at overall image understanding. It involves several processes such as pattern representation, feature selection, pattern proximity.

An image can be grouped based upon its properties such as brightness, pixel value and color. By converting pixels into superpixel groups, it reduces the computational cost and complexity. Each superpixel can be treated as a node in a graph and edge weights in graph based algorithms between two nodes the initial stage of clustering during each iteration it extracts the clusters from the previous iteration to obtain the better segmentation in gradient ascent based algorithms.

Segmentation can also be based on spatial coherence [6]. This includes two steps: Dividing or merging existing regions from the image and growing regions from seed points. Segmentation may be used for object recognition, image editing and image compression. The quality of image segmentation depends upon the digital image. For simple images, the segmentation process is clear and effective due to small pixels variations. For complex images, the utility for subsequent processing becomes very tough process.

3. Clustering

Clustering is a dividing of data into groups of similar objects [9]. Each group consists of objects that are similar between themselves and dissimilar to objects of other groups. The requirements that should be satisfied by clustering algorithms are scalability, dealing with different types of quality, ability to deal with noise, interpretability and usability.

Clustering of data is a method in which large sets of data are grouped into clusters of smaller sets of similar data. A clustering algorithms endeavor to find natural groups of components based on some resemblance. The clustering algorithm finds the centroid of a group of data sets. To evaluate cluster membership, most algorithms evaluate the distance between the cluster centroids and a point. The output from a clustering algorithm is basically a statistical description of the cluster centroids with the number of components in each cluster.

Some images may not have appropriate keywords to describe them and therefore the image search will become difficult. One of the solution in order to defeat this problem is “relevance feedback” technique [11] that utilize user feedback and hence reduces possible errors and redundancy [1], [12]. This technique uses a Bayesian classifier [13], [14] which deals with positive and negative feedback.

4. Clustering techniques

Clustering technique attempts to access the relationship among patterns of the data set by organizing the patterns into groups or clusters such that patterns within a cluster are more similar to each other patterns belonging to different patterns.

Clustering refers to the classification of objects into groups according to certain properties of these objects.

Clustering techniques can be categorized into supervised clustering and unsupervised clustering. Supervised clustering demands human interaction to decide the clustering criteria and the unsupervised clustering decides the clustering criteria by itself. Supervised clustering includes hierarchical approaches such as relevance feedback techniques [2], [12] and unsupervised clustering includes density based clustering methods. These clustering techniques are done to perform image segmentation. A variety of clustering techniques have been introduced to make the segmentation more effective. The clustering techniques which are included in this paper are Hierarchical clustering [4], Partitional clustering, K-means clustering and Fuzzy clustering.

4.1. Hierarchical Clustering

One of the well- known technologies in information retrieval is hierarchical clustering [3], [4]. This technique is based on the use of proximity matrix indicating the similarity between every pair of data points to be clustered. The final result is a tree of clusters representing the nested group of patterns and similarity levels at which groupings transform. The resulting clusters are always created as the internal nodes of the tree. The clustering methods differ in regard to the rules by which two small clusters are merged or a large cluster is split. The two main classification of algorithms used in the hierarchical clustering framework are agglomerative and divisive. Agglomerative algorithms request to merge clusters to be larger by starting with N single point clusters. This algorithm can be divided into three classes.

(i) Single link algorithm

(ii) Complete link algorithm

(iii) Minimum variance algorithm

In single link algorithm, it merges two clusters based on the minimum distance between the data samples from two clusters. In complete link algorithm, it incorporates the maximum distance between the data samples in clusters. In minimum variance algorithm, it combines two clusters to minimize the cost function to form a new cluster. Divisive clustering begins with the same cluster in entire dataset. It follows a reverse splitting of the dataset until the single point clusters are attained on leaf nodes. It follows a reverse clustering approach against agglomerative algorithm.

4.2. Partitional clustering

It uses an iterative optimization procedure that aims at minimizing an objective function which measures the goodness of clustering. The cluster centroids are usually computed based on the optimality criterion such that the objective function is minimized.

Partitional algorithms are divided into two types.

(i) Partitioning relocation algorithm

(ii) Density based partitioning

4.3. K-means clustering

It is the simplest method in supervised classification. It does not require training data. It is an iterative procedure. K-means clustering algorithm clusters the data by iteratively computing a mean intensity for each class and segmenting the image by classifying each pixel in the class with the closest mean. Clustering based on the optimization of an overall measure is a fundamental approach explored since the early days of pattern recognition. The most popular method for pattern recognition is K-means clustering. In K-means clustering a centroid vector is computed for every cluster. The centroid must be chosen such that it should minimize the total distance within the clusters [3].

Steps:

(i) Choose K initial clusters $z_1(s), z_2(s), \ldots\ldots z_k(s)$

(ii) At kth iterative step, distribute the samples x among K clusters using the relation

$x \in C_i(k)$ if $\|x - z_m(k)\| \leq \|x - z_n(k)\|$

For $m=1,2,\ldots\ldots K$, $m \neq n$, where $C_i(k)$ denotes the set of samples whose cluster centre is $z_n(k)$

(iii) Compute new cluster centers $z_n(k+1)$, $n=1,2,\ldots..K$, such that the sum of squared distance from all points in $C_i(k)$ to new cluster is minimized. The measure which minimizes this is

only the sample mean of $C_i(k)$.So the new cluster is given by

$$Z_n(k+1) = 1/N_n \sum x , \quad n = 1,2,.....K$$

Where N_n is the number of samples in $C_n(k)$

(iv) If $z_n(k+1)$, n = 1,2,.....K, the algorithm has converged and the procedure is terminated. If not go to step 2.

4.4. Fuzzy clustering

Clustering methods can be classified as either hard or fuzzy depending on whether a pattern data belongs exclusively to a single cluster or several clusters with different values [8]. In hard clustering, a membership value of zero or one is assigned to each pattern data. In fuzzy clustering, a value between zero and one is assigned to each pattern by a membership function.

Fuzzy clustering methods can be considered to be superior to those of their hard counterparts since they can represent the relationship between the input pattern data and clusters. It is used to minimize the heuristic global cost function. Fuzzy k-means clustering algorithm iteratively updates the cluster centroid and estimates the class membership function by using the gradient descent approach.

5. Conclusion

Segmentation is an important process in advance image analysis and computer vision and it is an ongoing research area although a dense literature is available [7]. A survey of highlighting different clustering techniques used for image segmentation has been presented. Image segmentation basics, Clustering basics and Clustering techniques in image segmentation have been analyzed. Using clustering algorithms, image segmentation can be done in an effective way. Clustering techniques are used to enhance the efficiency of the image retrieval process.

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