Marker-Controlled Watershed Segmentation using Multi-Otsu Thresholding

I Motivation

Traditional marker-based watershed segmentation methods use binary thresholding for generating the foreground and background required for marker generation. However, in complicated settings, such binary thresholding fails to provide optimum results. Hence, we propose a marker-controlled watershed algorithm assisted by K-level Otsu thresholding for segmentation of images in elaborate settings.

II Proposed Methodology

We propose an image processing pipeline which utilizes K-Means clustering to obtain the optimal number of threshold levels for multi-level otsu thresholding. The multi-level thresholded image is then used to generate markers which are used to segment the given image using watershed algorithm.

II.1 Estimation of Optimal Threshold level using K-Means Clustering

K-Means clustering is a segmentation algorithm which assigns each data points to one of K groups based on the features that are provided. For images the features used are the red, green and blue values of the pixels and their relative position. We subject our input image to K-Means clustering for multiple values of K. For each K, we calculate a metric known as Silhouette Score. Silhouette refer to a method of interpretation and validation of consistency within clusters of data. The silhouette values interpret how close each point in a cluster is to points in the neighbouring clusters and thus, provides a way to asses the number of clusters.The measure ranges from -1 to +1. A high silhouette value implies that the clustering configuration is appropriate and a low value implies poor clustering. Hence, we calculate the silhouette score for all values of K and obtain an optimal number of cluster by selecting the K with the maximum silhouette value. The number of threshold levels(k) used for the multi-level Otsu threshloding is one less than the number of clusters obtained.

II.2 Multi-Otsu Thresholding

Otsu Thresholding is a method to find the best value of threshold. Otsu's thresholding method involves iterating through all the possible threshold values and calculating a measure, which in this case is intra and inter class variance, of spread for the pixel levels on each side of threshold, i.e. the pixels that either fall in background or foreground. The aim is to find the threshold value where the sum of the spread of foreground and background is at its maximum. It is being widely used for finding an optimal threshold for differentiating two classes. We have implemented Multi level Otsu, which can effectively find *k - 1* thresholds for *k* classes. We already have the optimum number of classes from silhouette value. Next, we iterate through all possible combination of threshold values and find intra and inter class variance. Its *argmax* gives us the optimum combination of thresholds.

II.3 Marker Generation

We generate markers by obtaining the regions in the image corresponding to the foreground and background in the image. Since, we follow a multi-level thresholding approach, we have a foreground corresponding to each thresholded level in the image. Hence, we develop an approach to obtained the foregrounds with a high confidence level corresponding to each thresholded segment. In order to obtain the foreground corresponding to each segment, we use a feature map containing on the pixels corresponding to the particular segment. We apply a distance transform based thresholding on this image to obtain the *sure foreground.* The *sure foregrounds* corresponding to each thresholded segment are then merged on to a global map.

Running connected components labelling on this global map provides the markers to be used for Watershed Segmentation.

II.4 Watershed Segmentation

The markers obtained used for the application of Watershed Algorithm for segmenting objects in the input image.

III Experiments

We have tested the proposed algorithm on a collection of 10 images obtained from the *The Berkeley Segmentation Dataset BSDS500*. We have performed extensive experimentation to obtain the most generalized attributes proving the most optimal results.

First we tried K-means clustering for image segmentation. We have implemented our own version of it. The major drawback, apart from providing number of clusters(which we are already finding from silhoutte plot), is that the K means algorithm does not maintain spatial integrity. Because of this, if there are some irregularities in the color pattern in certain parts of the image, it might introduce some noise in segmentation. To deal with this, we introduced certain weight for position of pixel in the image by adding x and y coordinates in the distance term. Tuning the weight of pixel positions in the distance term is a difficult job and it usually varies from image to image. Therefore, we shifted to watershed segmentation.

For watershed segmentation, we have tried several variants of the thresholding applied to the input image. We had applied multi-level Otsu thresholding on (1) hue value in the HSV domain, (2) gray scale image, and (3) B, G and R channels individually followed by merging the results corresponding to each channel by taking an average of the three. The last one provided the most optimum results in our case. Another experiment done on our part is that while obtaining the *sure foreground* corresponding to each thresholded segment, we apply the distance transform on (1) the segment itself (2) the segments with the morphological operation opening applied on it. However, no significant change was observed in the two cases.

IV Libraries

Initially we had implemented the watershed algorithm in C++ but the execution time for the code was somewhat big and the results obtained were not very satisfying as compared to watershed implementation of OpenCV because of the over segmentation issue. Hence we have used the implementation of watershed algorithm available in OpenCV.
Finally, we have used OpenCV, Numpy and scikit-learn library for this project.

V Conclusion

Object segmentation is an active research topic at research labs throughout the world. It is being widely used in majority of the computer vision applications. With an increase in computation power, the world has shifted to the use of Deep learning to achieve state-of-the-art accuracy on several benchmarked datasets. However, we propose an image processing based algorithm which combines K-Means clustering and the watershed segmentation algorithm assisted by Multi-level thresholding to produce commendable results on a public dataset. Even though approaches involving deep learning paradigm produce much better results than what we have obtained, there are still certain limitations that need to be addressed. As future works, the algorithm proposed by us can be used to generate priors for the deep-learning based segmentation networks to generate better results than the existing ones.