CSC8628 – Image Informatics Assignment

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1 Problem Statement

Food Image segmentation is a task that is beneficial for developing health-related applications such as estimating nutritional information of food. With this context in mind, we are given a dataset of food images, and the task is to develop an algorithm to segment different food items present in the image.

2 Efficient Graph Based Algorithm

The algorithm that we start with is an Efficient Graph Based Algorithm [1]. The algorithm is based on similarity and dissimilarity of elements in a component. As the image is transformed into a graph with pixels as nodes and edges connecting these pixels, we want the edges between two nodes in the same component to have low weights and, edges between different components to have high weights.

In order to understand the above algorithm, we first need to define a few terms that we use to differentiate between different components.

2.1 Internal Difference

Internal Difference of a component is defined as the largest weight in the minimum spanning tree of the component.

2.2 Difference between Components

The difference between two components is the minimum weight edge connecting the two components.

2.3 Threshold Function

Threshold function is used to control the degree to which the difference between components must be greater than their internal differences for there to be evidence of a boundary between them.

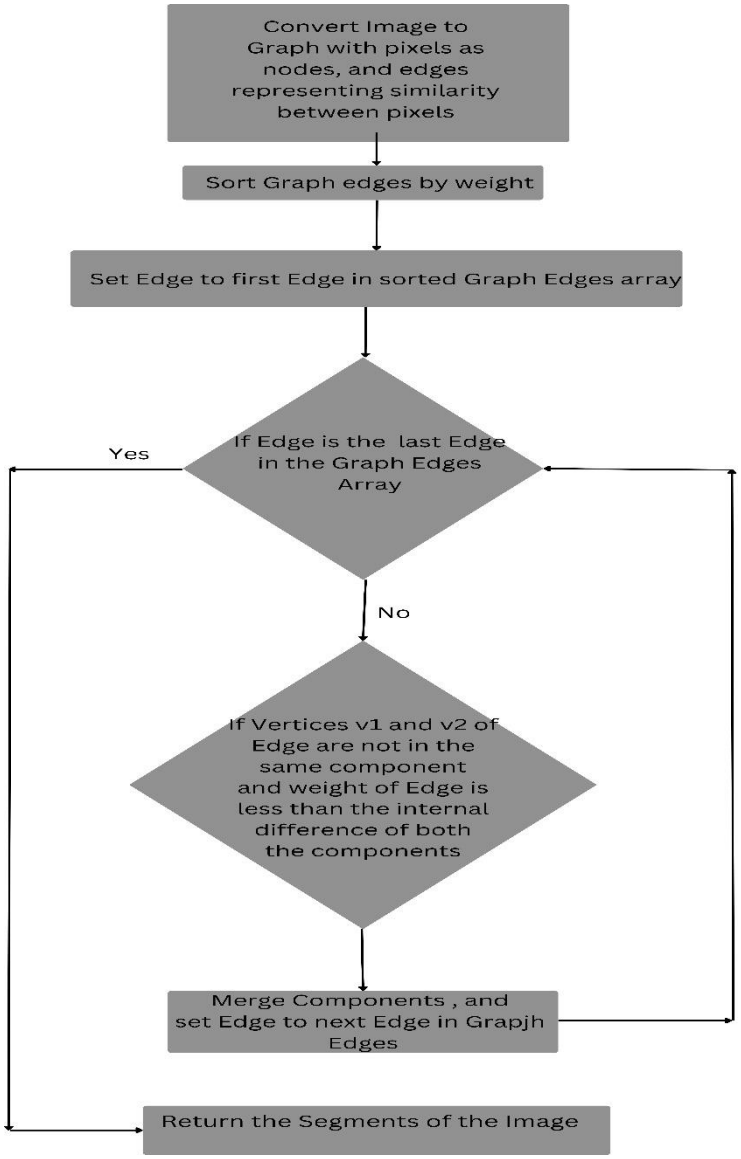

Fig. 1. Graph Based Algorithm

2.4 Algorithm

The algorithm follows a greedy approach and compares edge nodes based on their internal difference and difference between components. If edge nodes belong to different components and their internal difference is less than the component difference, then we merge the nodes, otherwise, we do nothing. To control the degree to which the difference between two components must be greater, threshold function is used.

3 Graph Based Algorithm with Mean shift Filtering.

We try another approach to improve the performance of the previous graph-based algorithm [2]. We apply Mean shift Filtering before applying graph-based algorithm. Also, a gaussian filter is applied to improve performance as shown by previous results [1]. The primary idea in Mean Shift algorithm is to shift data points iteratively towards the mode of the underlying probability density function.

The Mean Shift algorithm has several advantages, including its ability to handle irregularly shaped clusters and adapt to varying cluster densities. Food images tend to have irregular shaped clusters and thus, Mean Shift is a good choice.

4 Graph Based Algorithm with Mean shift and Background Mask

After evaluating the results of previous two algorithms, we observed that our algorithms can't distinguish between the background and foreground in the image. In order to fix this weakness of our algorithm, we use threshold processing to separate the background from the original image and add it to the segmented image after applying graph-based algorithm [3].

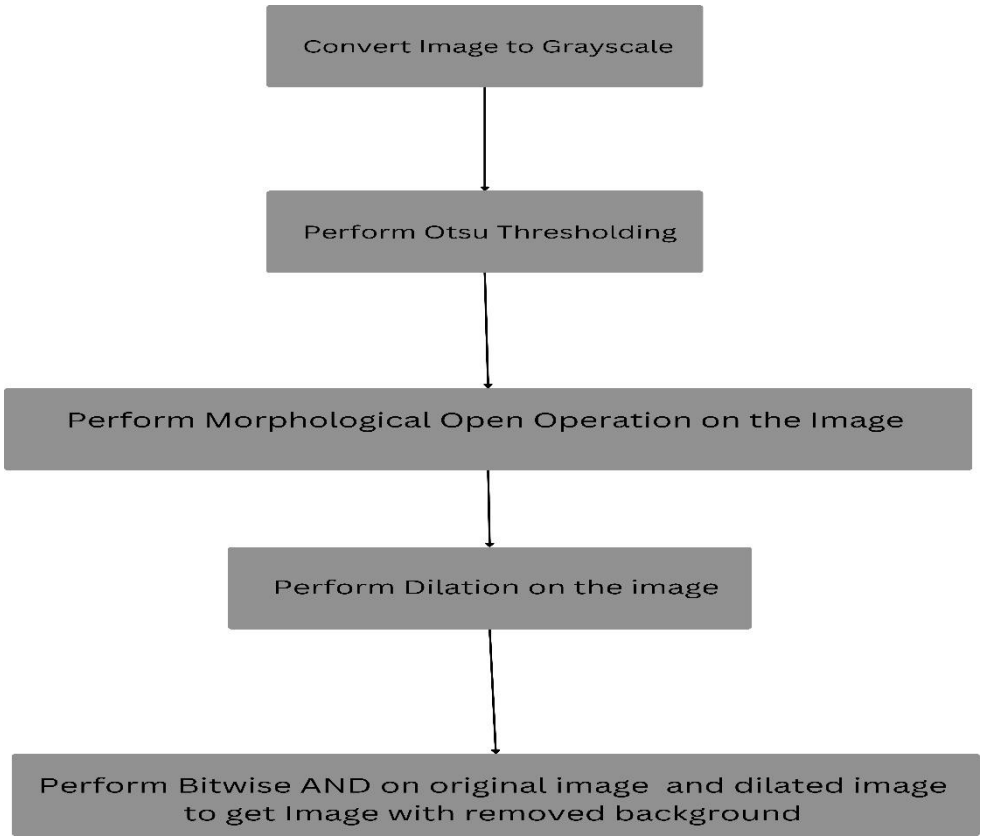

Fig 2. Graph Based Algorithm with Mean Shift and Background Mask

To get the background mask, we first convert the image to grayscale. Then, we apply Otsu's thresholding technique and inverse the result. Next, to clean the object's outline, we perform morphological opening operation. Morphological Open operation means shrinking the bright regions first, and then expanding them. Finally, to get a hold of the background, we dilate the image which expands the bright regions. Then, perform Distance Transform which calculates the distance of each white pixel to the closest black pixel. The foreground is obtained by applying a threshold on values we get by applying Distance Transform. We simply apply this background mask to the segmented image to get our final segmented image.

5 Libraries and Functions Used

Following Libraries and Functions are used to implement the above mentioned algorithms and display results:

1. Numpy and Matplotlib
    a. These were used for array manipulation on image arrays, and to display different stages of image segmentation.
2. CV2
    a. IMREAD and COLOR
        i. These 2 functions are part of CV2 library and were helpful in reading images from directories and changing images from RGB to grayscale and vice versa.
    b. Threshold, MorphologyEx and Dilate
        i. These functions of CV2 library proved to be quite valuable as they are implementations of quite common image processing operations as their name suggests. Threshold even had a flag to apply Otsu's thresholding.
3. Sklearn
    a. Meanshift and Estimate_Bandwidth
        i. Meanshift is an implementation of the mean shift algorithm.
        ii. Estimate_Bandwidth is used to calculate the bandwidth parameter that influences the size of the region around each data point within which the algorithm considers other points for determining the mode. A smaller bandwidth leads to smaller, more localized clusters, while a larger bandwidth results in larger, more spread-out clusters.
4. PIL
    a. Image
        i. Image is used to generate RGB images from graphs.

6 Results on Sample Images

Now that we have gone through all the algorithms and functions/libraries used, let's look at a few example images and evaluate how well the algorithms perform.

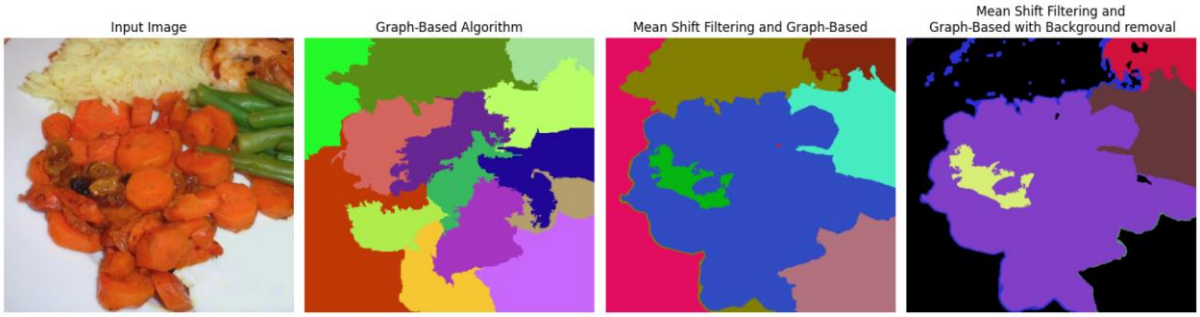

Fig 3. Segmentation Result on Sample Image 1

Figure 3. shows the Segmentation result of all 3 algorithms on a sample Image. The Graph-based algorithm performs well, however, there are certain major issues with it. Firstly, the background is not clearly distinguished from the food. What this means is that our algorithm does not compare components across the image. It simply tries to identify boundaries between adjacent components. The output of Graph-Based algorithm is significantly improved when we apply Mean Shift filtering to the image first. Small different clusters are combined, and the segmented image becomes much clearer. It is important to note that not all small clusters are merged into its adjacent regions. For example, the small beans present amongst carrots are segmented separately, due to their internal difference being more than its surrounding region. Finally, applying a mask that segments the background makes the segmentation clearer. However, few segments are removed during this process such as the rice above carrot and parts of shrimp.

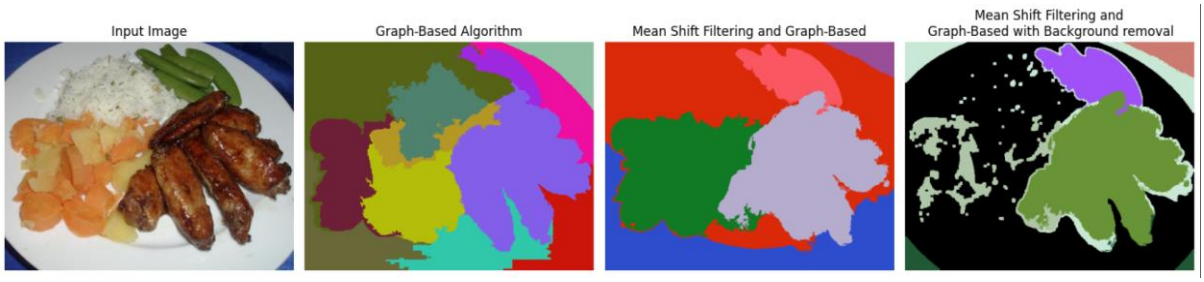

Fig 4. Segmentation Result on Sample image 2

Fig 4. shows another set of results for a sample image. Graph-Based algorithm performed quite well for this image, clearly separating different elements on the dish. Food components with very different and bright colours are easily separated by the algorithm. However, since the plate is also white, rice from the image is merged with the background. Similar issue happens even after applying Mean shift filtering to the image. Background Removal has again covered some components which are similar in intensity to the plate, such as rice.

Finally, let's evaluate how our model performs on the dataset based on Mean IoU(Intersection over Union) scores. Below is a distribution of MIoU scores for all 3 algorithms on the dataset.

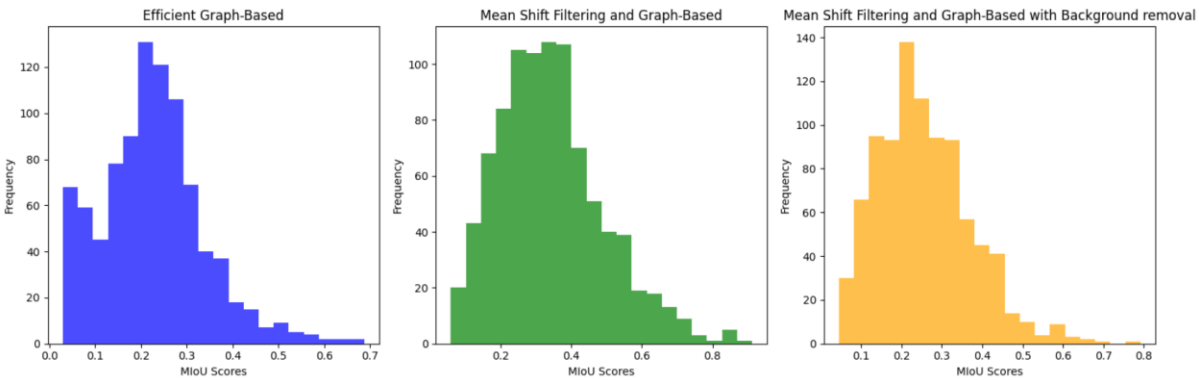

Fig 5. MIoU score Distribution for all 3 algorithms.

Graph-Based algorithm has most scores in the range of 0.05 to 0.25. This is due to the algorithm not being able to distinguish between the food and background properly. It performed surprisingly well on some images though, even achieving scores of more than 0.5. Next, Mean Shift filter and Graph-Based algorithm performed quite uniformly, with most scores being in the range of 0.2 to 0.45. Mean shift filter significantly improved the performance and refined the output of Graph-based algorithm. Finally, the third algorithm with the addition of background removal performed quite poorly. Most scores are in the range 0.05 to 0.2. The addition of background removal proved to be a double-edged sword. For some images it worked quite well, even achieving scores above 0.6. However, for majority of segmentations, it covered some part of food item as background and thus reduced the overall segmentation score.

Algorithm	Average MIoU Score
Efficient Graph-Based Algorithm	0.22
Mean Shift Filtering with Graph-Based	0.34
Mean Shift Filtering with Graph-Based and Background Removal	0.25

Table 1. Average MIoU Scores

7 Conclusion

We started with an Efficient Graph-Based algorithm to segment different components in food Images [1]. The algorithm performed quite well on samples, however, to overcome the weakness of not being able to identify similar components across images, we apply Mean shift filtering to the image [2]. Applying mean shift filtering significantly improved the performance of the algorithm and generated quite satisfactory results. This algorithm is quite stable, compared to other two. However, not being able to properly distinguish between the background and food was proving to be an issue with the algorithm. We try to improve this by generating a binary mask of the background and apply it to the final segmented image [3]. This worked well in a few cases, and in majority of the cases it covered some part of food elements, which further reduced the performance of the algorithm.

References

1] P. Felzenszwalb, D. Huttenlocher,“Efficient Graph-Based Image Segmentation”, Intl Journal of Computer Vision, 2004, 59 (2)

2] C. Pantofaru and M. Hebert, "A Comparison of Image Segmentation Algorithms", Sept. 2005.

3] https://www.geeksforgeeks.org/image-segmentation-with-watershed-algorithm-opencv-python/?ref=lbp