Comparative Analysis of Edge-Based, Clustering-Based and Watershed Segmentation with Morphological Post-Processing using IoU Metric

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ABSTRACT – Image segmentation is an preliminary process for various applications in computer vision, including object recognition and medical imaging. In this paper we experimented a set of classical edge-based and region-based segmentation methods on the Berkeley Segmentation Dataset. Canny edge detection served as a typical edge-based method, while K-Means clustering and Watershed segmentation operate as region-based methods. Morphological closing was used as a post-processing technique to enhance the boundaries of segments. Optimal parameters for each method were selected through parameter tuning using multiple combinations. Performance was quantitatively evaluated using the Intersection/Union (IoU) score. The results show that region-based methods generally outperform edge-based segmentation in terms of IoU on the Berkeley Segmentation Dataset.

Keywords: Image Segmentation; Edge Detection; K-Means; Watershed; IoU

1. INTRODUCTION

Image segmentation is the process of separating a view into regions, which typically corresponds to objects or partitions in the image. Accurate segmentation provides critical information for high-level image operations such as object recognition and tracking. Traditional segmentation approaches can be broadly classified as edge-based and regionally scaled. Edge-based techniques determine boundaries by detecting distributional changes; Canny edge detection is one example. Region-based methods, on the other hand, group pixels based on distributional similarities such as color. K-Means clustering and Watershed segmentation are examples of this category. Morphological closing is designed to fill in small structures and smooth object boundaries. The performance of the method is evaluated using the Intersection Over Union (IoU) metric.

2. MATERIALS AND METHODS

2.1 Datasets

We utilized the Berkeley Segmentation Dataset (BSDS500)[1], which contains natural images accompanied by human-marked ground truth segmentations. The dataset was split into training, validation, and test subsets. Each image is resized to a uniform size to standardize processing, and the corresponding ground truth masks were loaded for evaluation.

2.2 Edge-Based Segmentation with Canny Edges were detected using the gradient-based Canny algorithm. Morphological closing was applied to improve the continuity of the boundaries. The sigma coefficient, which determines the threshold ranges in Canny, and the closing radius were tested in different combinations to select the most suitable parameters *(σ = 0.2, 0.33, 0.5; radius = 0, 3, 5)*.

2.3 Region-Based Segmentation with K-Means The K-Means clustering method grouped pixels according to color similarity to segment the image. Pixels belonging to the largest cluster were considered as foreground, and masks were generated from these regions. Morphological closing was additionally applied to maintain boundary continuity. The number of clusters (k) and the closing radius were tested in different combinations (k = 2, 3, 4; radius = 0, 3, 5) to select the optimal parameters.

2.4 Watershed Segmentation Method Watershed segmentation treats pixel intensities as a topographic surface and identifies basin regions corresponding to objects. Local maxima were defined as markers, with the footprint size controlling the neighborhood for peak detection and the closing radius applied after segmentation; both were used as adjustable parameters *(footprint = 3, 5, 7; radius = 0, 3, 5)*.

3. RESULTS

3.1 Performance Measures

The Intersection-over-Union (IoU) metric was used to quantitatively evaluate segmentation performance. Each method was tested on the BSDS500 test set, and optimal parameters were selected through tuning. Edge-based Canny segmentation achieved moderate IoU scores but suffered from fragmented boundaries. K-Means clustering consistently outperformed edge-based segmentation, producing smoother and more consistent segments. Watershed segmentation achieved performance comparable to K-Means when appropriate footprint and closing radius parameters were applied. Post-processing with morphological closing improved the IoU of all methods by filling small gaps and improving object boundaries. Table 1 summarizes the best IoU scores for each method.

Table 1: IoU Scores for Segmentation Methods

Method	**Optimal**	**Parameters**	**IoU Score**
Canny	$\sigma = 0.5$	closing = 5	0.527
K-Means	k = 2	closing = 5	0.776
Watershed	fp = 3	closing = 5	0.532

4. CONCLUSIONS

This study presents a systematic comparison of edge-based and region-based segmentation techniques on natural images. Morphological occlusion is effective in improving segment boundaries for all methods. K-Means clustering provided the best overall segmentation performance, followed by Watershed segmentation when parameters were optimized. Edge-based segmentation is suitable for fast boundary detection but may be insufficient for accurate region identification. Future work could explore deep learning-based segmentation to further improve performance on complex images.

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