

Performance Analysis of Region-based and watershed Segmentation Techniques using Blood Smear Images

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Abstract

Image segmentation plays a significant role in medical image analysis by partitioning an image into meaningful regions that facilitate the identification and analysis of anatomical structures. It remains a pivot area of research due to the numerous challenges associated with accurately partitioning images into distinct regions. Accurate segmentation of blood smear images is essential for computer-aided diagnosis, disease detection, and hematological analysis. This study presents a comparative performance analysis of two widely used image segmentation techniques, namely Region-Based Segmentation and Watershed Segmentation, using blood smear images. The segmentation performance is quantitatively evaluated using standard metrics, including the Jaccard Coefficient, Dice Coefficient, True Positive Rate (TPR), and True Negative Rate (TNR).

Keywords: Region-based segmentation, Watershed segmentation, Jaccard coefficient, Dice coefficient

1. Introduction

An image can be represented as a two-dimensional function of spatial coordinates, $(f(x, y))$, where the value of the function at any given coordinate $((x, y))$ corresponds to the intensity of the image at that point. Digital image processing involves the application of computational algorithms to enhance image quality, reduce noise and other unwanted artifacts, and extract meaningful information for further analysis. These techniques play a significant role in various fields, including medical imaging, remote sensing, pattern recognition, and computer vision. Among the diverse image processing operations, image segmentation is considered one of the most critical steps, as it partitions an image into meaningful regions and facilitates accurate interpretation and analysis. This paper primarily focuses on image segmentation, discussing the underlying concepts, commonly employed methods, and widely adopted algorithms. Furthermore, a comparative evaluation of selected segmentation techniques is conducted using test images. The implementation and analysis of these methods are performed using MATLAB software. Image segmentation is a fundamental mid-level image processing technique employed to analyze and interpret digital images. It involves partitioning an image into multiple non-overlapping regions by grouping pixels with similar characteristics, such as gray level, color, texture, intensity, or other relevant features. The objective of segmentation is to identify homogeneous regions within an image, thereby facilitating the extraction of meaningful information from the region of interest (ROI) and supporting subsequent tasks such as object recognition, scene understanding, and image annotation. Image segmentation aims to achieve a domain-independent decomposition of an image into a set of visually distinct and homogeneous regions based on



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predefined properties. A primary goal of the segmentation process is to accurately distinguish objects from the background, thereby enabling effective image analysis.

2. Literature Review

Image segmentation is used to divide objects from the background. It is an essential step for doing the other steps of digital image processing like feature extraction, classification, and detection. Several techniques have been developed for image segmentation. Since there is no general solution to the image segmentation problem, these methods often have to be combined with image processing in order to solve an image segmentation problem related to that domain effectively. Image segmentation techniques are categorized into two approaches, namely discontinuity based and similarity based approach. In the former method the image is segmented based on the discontinuity and in the latter the image is segmented based on the similarity. The techniques such as thresholding techniques, region growing techniques and region splitting and merging falls under this category. These techniques divide the image into regions having similar set of pixels. The clustering techniques divides the image into set of clusters having similar features based on some predefined criteria. There are mainly five categories of segmentation techniques such as thresholding based, region based, clustering based, edge based and watershed based techniques.

2.1. Preprocessing

Image pre-processing is the initial step in the image segmentation pipeline because the presence of noise, low contrast, and intensity variations can significantly degrade segmentation quality. Before applying the segmentation algorithm, the input image is pre-processed to enhance its visual quality and improve important structural information. In this research, Anisotropic Diffusion Filtering is employed as the pre-processing technique due to its ability to effectively suppress noise while preserving significant image edges.

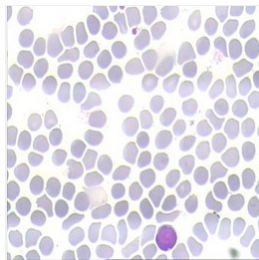


Fig. 1a. Original image

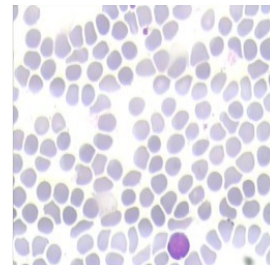


Fig. 1b. Enhanced Image

2.2. Thresholding based segmentation

In the threshold based method, the image is divided into two groups based on the threshold value. There are commonly three types of thresholding [5]. In global thresholding the image is divided into two groups by a single threshold. On the basis of T the output image $O(x, y)$ can be obtained from the original image $I(x, y)$ as

$$O(x, y) = \begin{cases} 1, & \text{if } I(x, y) > T \\ 0, & \text{if } I(x, y) < T \end{cases}$$

In local thresholding the value of T can vary over the image. In multiple thresholding multiple threshold values are used to divide the image into groups. The output image $o(x, y)$ can be computed as

$$O(x, y) = \begin{cases} 1, & \text{if } I(x, y) > T_1 \\ 0, & \text{if } I(x, y) < T_1 \end{cases}$$

$$nifI(x, y) < T1$$

$$pifI(x, y) \leq T0$$

The main advantage of the threshold technique is that the computation is simple and the execution speed is faster. Yet it lacks accurate results for image segmentation problems where there is no significant gray scale difference.

2.3. Region based segmentation

In region growing based segmentation the image is divided into various regions based on the growing of seeds. These seeds can be selected manually or automatically. In region splitting and merging again two methods are used such as splitting and merging for segmenting an image into different regions. Splitting stands for iteratively dividing an image into regions having similar characteristics and merging contributes to combining the adjacent similar regions.

Steps for region splitting and merging are given here.

Let 'p' be the original image and T be the particular predicate.

- First of all the R1 is equal to p.
- Each region is divided into quadrants for which $T(R_i) = \text{False}$.
- If for every region, $T(R_j) = \text{True}$, then merge adjacent regions R_i and R_j such that $T(R_i \cup R_j) = \text{True}$.
- Repeat step 3 until merging is impossible.

2.4. Clustering based segmentation

propose an enhanced clustering-based image segmentation algorithm to address the limitations of the conventional K-means algorithm in industrial ore particle image analysis. The work focuses on improving segmentation quality for ore particle size detection, where accurate segmentation is essential for estimating ore density, evaluating crushing efficiency, and optimizing mineral processing operations. The authors identify that traditional K-means suffers from random initialization of cluster centroids, slow convergence, sensitivity to illumination variations, and susceptibility to local optimum solutions, which often result in inaccurate segmentation [8].

Authors presents detailed evaluation of traditional image processing techniques and modern deep learning-based segmentation approaches. They emphasize the growing significance of image segmentation in computer vision because of its numerous applications in medical imaging, remote sensing, industrial inspection, surveillance, and agricultural monitoring. This article discussed the theoretical foundations of segmentation, the evolution of segmentation algorithms, benchmark datasets and evaluation metrics [1].

2.5. Watershed Algorithm for segmentation

Watershed is the ridge that divides areas shattered by different river system. It is a morphological gradient based segmentation technique. The water level will rise over the basins when a hole is made in each local minima and immerse the whole map in water. A dam is built when two different body of water meet and the progress continues until all the points in the map are immersed. Finally, the whole image is segmented by the dams which are then called watersheds and the segmented regions are called catchment basins [6]. Introduced a technique to automatically initialize the K-Means clustering algorithm according to the histogram of the image. All local maxima were taken and all the global maxima among them were considered as the initial centroid d. Further centroids were taken iteratively with the help of a maximized distance

measure. The DM was the product of height of local maxima and the distance from previous centroids. A drawback of this approach is the manual selection of centroids [2]. [3] proposed an approach for image segmentation using K-means method. Cosine distance measure was used for distance computation. The filtered result was segmented using Marker based Watershed algorithm. The metrics such as mean square error and peak signal to noise ratio were used for validation. [4] One of the major strengths of the paper is its systematic comparison of segmentation algorithms. The authors explain the fundamental concepts of each technique and discuss their performance in terms of computational complexity, segmentation accuracy, robustness to noise, and applicability to different image types. Here the authors classify image segmentation methods into four major types: threshold-based, region-based, edge-based, and deep learning-based segmentation. Thresholding methods, including global and adaptive thresholding, are described as computationally efficient and suitable for images with high contrast between objects and backgrounds. Yet these methods are sensitive to noise and illumination variations, making them less effective for ground truth images [7].

3. Experimental Results

The performance of the Region-Based Segmentation and Watershed Segmentation methods was evaluated using four widely accepted segmentation metrics: Jaccard Coefficient, Dice Coefficient, True Positive Rate (TPR), and True Negative Rate (TNR). The comparative results are presented in Table 1.

Table 1. Summary of experimental parameters.

Parameter	Watershed Segmentation	Unit Region based Segmentation
Jaccard Coefficient	0.22	0.42
Dice Coefficient	0.36	0.59
True Positive Rate	0.37	0.04
True Negative Rate	0.69	0.56

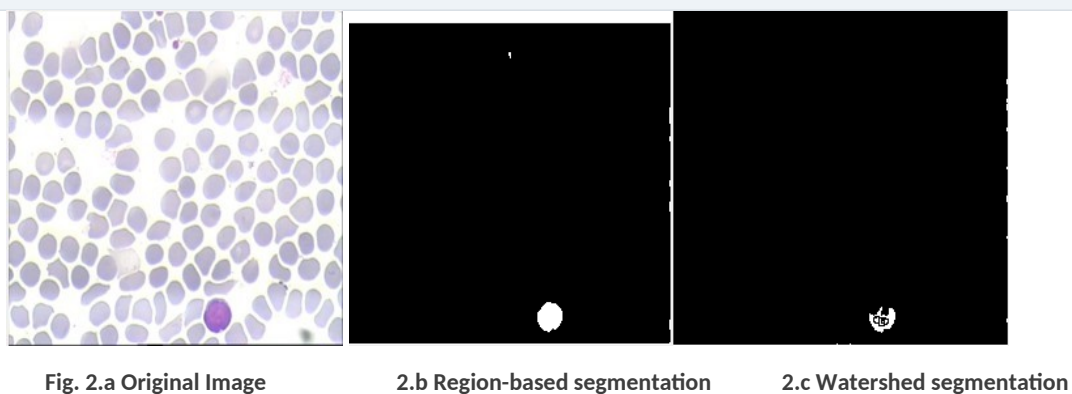


Fig. 2.a Original Image

2.b Region-based segmentation

2.c Watershed segmentation

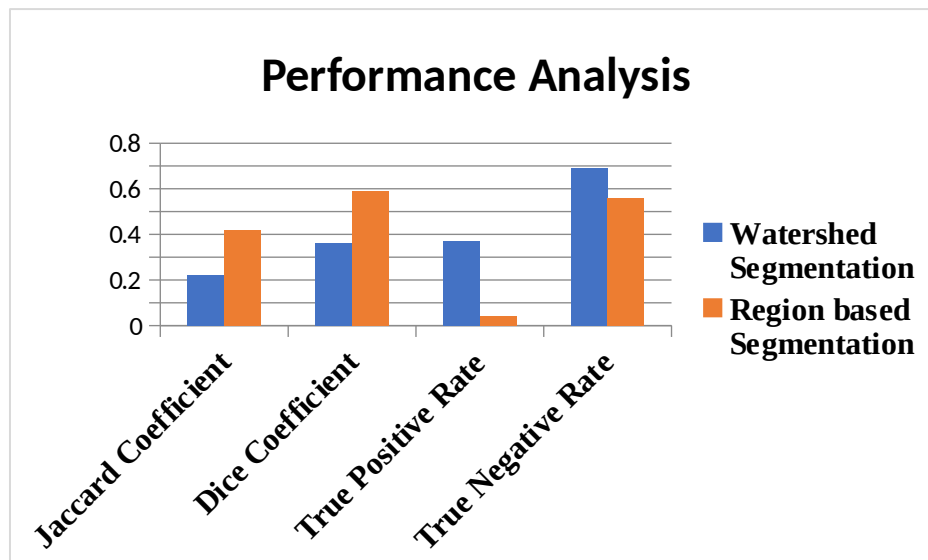


Fig.3 Performance Analysis

4. Discussion

Jaccard Coefficient measures the overlap between the segmented image and the ground truth, indicates that the Region-Based Segmentation method achieves a higher similarity score (0.42) compared to the Watershed Segmentation method (0.22). This suggests that the region-based approach provides a more accurate delineation of the target region. Similarly, the Dice Coefficient, another widely used overlap metric, is considerably higher for Region-Based Segmentation (0.59) than for Watershed Segmentation (0.36). The higher Dice value demonstrates that the region-based method produces segmentation results that are more consistent with the reference segmentation, thereby exhibiting superior segmentation accuracy. The True Positive Rate (TPR) evaluates the ability of the segmentation algorithm to correctly identify pixels belonging to the target object. Watershed Segmentation achieves a substantially higher TPR (0.37) compared to Region-Based Segmentation (0.04). This indicates that the watershed approach is more effective in detecting positive pixels and is comparatively more sensitive in identifying the object of interest. In contrast, the True Negative Rate (TNR) measures the capability of the algorithm to correctly classify background pixels. Watershed Segmentation also records a higher TNR (0.69) than Region-Based Segmentation (0.56), indicating better discrimination of background regions and less false-positive classifications.

Overall, the comparative analysis reveals distinct strengths for the two segmentation techniques. Region-Based Segmentation demonstrates superior performance in terms of similarity-based evaluation metrics (Jaccard and Dice coefficients), indicating better agreement with the ground truth segmentation. On the other hand, Watershed Segmentation achieves higher True Positive and True Negative Rates, reflecting greater effectiveness in pixel-level classification of both object and background regions.

5. Conclusion

Image segmentation has pivot role in image processing, with its effectiveness depending on the qualities of the input image and the application domain. This study compared the performance of Region-Based and Watershed segmentation techniques on blood smear images using standard evaluation metrics. The experimental results demonstrate that Region-Based Segmentation achieves better overlap accuracy, as reflected by higher Jaccard and Dice coefficients, whereas Watershed Segmentation exhibits superior true

positive and true negative rates, indicating better sensitivity and specificity. These findings ensure that no single segmentation technique is universally optimal, and the choice of method should be guided by the specific objectives of the application. Future work may focus on developing adaptive and hybrid segmentation frameworks that combine the strengths of multiple methods and incorporate artificial intelligence to enhance segmentation accuracy, robustness, and computational efficiency.

Data Source

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AI Usage Disclosure

The Author used ChatGpt, GPT-5.5, for Grammar Correction.

Author Contributions

A. Methodology, analysis, writing—original draft, writing—review and editing.

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