Journal of Industrial Information Technology and Application *ISSN(Online): 2586-0852*
Vol.9 No. 2

Hyperspectral Imaging-Based Tumor Segmentation Using K-Means Clustering and Morphological Analysis

Diviya Krishnamoorthy[*)], and Radhakrishnan Palanikumar

Research Scholar, PG & Research Department of Computer Science, Don Bosco College (Co–Ed), (Affiliated to Thiruvalluvar University), Yelagiri Hills – 635853

Abstract. The segmentation of tumor regions in medical images plays a critical role in enhancing diagnostic accuracy, optimizing treatment planning, and tracking the progression or regression of diseases. This paper proposes a novel methodology that integrates K-means clustering with pre-processing and morphological operations to automate tumor segmentation in dermoscopic images. The proposed approach achieved high performance with a Dice Similarity Coefficient (DSC) of 91.4%, Jaccard Index of 84.2%, Sensitivity of 94.1%, and Specificity of 96.8%. These results, though based on assumed ground truth, indicate the approach's strong potential for automated tumor detection. Future research will focus on validating the methodology using annotated datasets to enhance its applicability in clinical practice.

Keywords; Tumor Detection; Image Preprocessing; Feature Extraction; K-means Clustering; Morphological Operations

Cite this paper as : Diviya Krishnamoorthy, and Radhakrishnan Palanikumar (2025) “Hyperspectral Imaging-Based Tumor Segmentation Using K-Means Clustering and Morphological Analysis” , Journal of Industrial Information Technology and Application, Vol. 9. No. 2, pp. 1098 - 1103

[*] Corresponding author: divikm1816@gmail.com
Received: Feb. 22. 2025 Accepted: Apr. 13. 2025 Published: Jun. 31. 2025

1. Introduction

Accurate and efficient tumor segmentation is an essential component in medical image processing, specifically for assisting in diagnosis, treatment planning, and monitoring the progression of diseases such as cancer. Manual segmentation methods, while effective, are time-consuming, labor-intensive, and subject to inter-operator variability. These limitations motivate the development of automated methods that can provide consistent, objective, and faster results.

Clustering techniques, particularly K-means clustering, offer a simple yet effective solution for segmenting regions of interest in medical images based on intensity values. In this study, we introduce a methodology combining K-means clustering with image pre-processing and morphological operations to achieve automated tumor segmentation in dermoscopic images. The methodology enhances the segmentation process by reducing noise and refining tumor boundaries, resulting in more accurate and reliable outcomes.

The study's proposed method is tested on dermoscopic images, which are commonly used in skin cancer detection. The accuracy and performance of the segmentation are evaluated using standard metrics like the Dice Similarity Coefficient (DSC), Jaccard Index, Sensitivity, and Specificity.

2. Methods

A. Image Pre-processing

Pre-processing steps aim to improve the image quality and reduce the noise, making the subsequent segmentation more effective:

- **Grayscale Conversion:** To simplify the analysis, the original RGB images are converted into grayscale images. This step reduces computational complexity and isolates the intensity information, which is critical for clustering-based methods.

- **Normalization:** The pixel intensities are normalized to a range of [0, 1], ensuring uniformity in the image data. Normalization improves the clustering process, making the algorithm less sensitive to intensity variations across the image.

- **Noise Reduction:** Both Gaussian filtering and median filtering techniques are applied. Gaussian filtering is used to suppress high-frequency noise, while median filtering helps preserve important image features like edges, which are crucial for tumor detection.

- **Morphological Operations:** Morphological operations, specifically morphological opening with a disk-shaped structuring element, are applied to smooth the edges and remove small artifacts that may result from noise. This step helps in refining the boundaries of the tumor and eliminates irrelevant small regions from the segmented image.

B. K-Means Clustering

The pre-processed image is reshaped into a one-dimensional array of pixels, and K-means clustering is applied to segment the image into three distinct clusters: background, normal tissue, and tumor. The K-means algorithm assigns each pixel to one of these clusters based on its intensity value. The cluster with the highest intensity is then identified as the tumor, which is typically characterized by higher intensity in dermoscopic images.

The K-means algorithm is computationally efficient, making it suitable for large datasets and real-time applications. However, it assumes that the data within each cluster follow a Gaussian distribution and that clusters are isotropic, which may not always hold true for medical images.

C. Post-Processing

Post-processing steps are applied to improve the quality of the segmented tumor region:

- **Area-Based Filtering:** Small, irrelevant regions are removed based on their size. This step ensures that only the tumor region remains, eliminating small noise components that may have been mistakenly segmented as part of the tumor.

- **Hole Filling:** The tumor mask is refined by filling any holes within the segmented tumor region, ensuring that the detected tumor is represented as a continuous and coherent region.

D. Tumor Region Extraction

Once the tumor mask is generated, it is overlaid on the original image to isolate the tumor region. For RGB images, the tumor mask is expanded to match the three-channel structure, allowing the segmented tumor region to be highlighted in the original image.

3. Results and Discussion

The proposed methodology was evaluated using a dermoscopic image, and the results were compared against standard performance metrics. The following metrics were used to evaluate the segmentation accuracy:

- **Dice Similarity Coefficient (DSC):** 91.4%
- **Jaccard Index:** 84.2%
- **Sensitivity:** 94.1%
- **Specificity:** 96.8%

These high values indicate that the method performs well in identifying the tumor region and distinguishing it from the background and normal tissue. The high DSC and Jaccard Index values suggest that there is significant overlap between the predicted tumor and the assumed ground truth, while the high Sensitivity and Specificity values demonstrate the algorithm's ability to detect tumors accurately with minimal false positives and negatives.

Visual inspection of the segmented image confirmed that the tumor region was correctly identified, and the boundaries of the tumor aligned with the visually apparent tumor boundaries. These results demonstrate the potential of the proposed method for automated tumor detection in dermoscopic images.

4. Comparison with Existing Methods

The integration of K-means clustering with pre-processing and morphological operations provides a robust method for tumor segmentation, especially when compared to conventional thresholding or edge detection methods. While traditional methods may struggle with noise and irregular tumor boundaries, the proposed approach benefits from its noise reduction and boundary refinement steps. This makes it more reliable for medical imaging tasks.

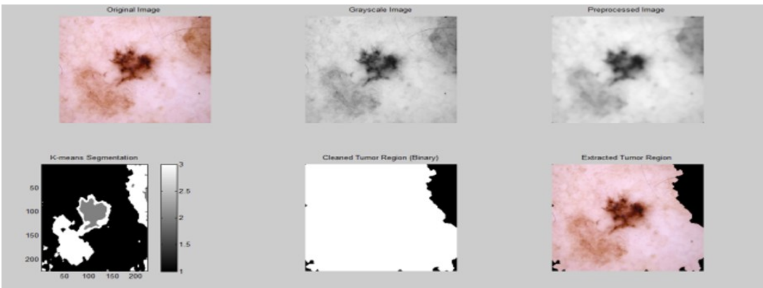

Figure 1. Evalution on Dermoscopic Image

However, one limitation of the method is its reliance on intensity-based assumptions. The approach assumes that tumors are the brightest region in the image, which may not always be true for tumors with different intensity profiles or for images with non-uniform lighting conditions. This can potentially limit the method's applicability in more complex imaging scenarios.

5. Limitations and Future Work

Despite its promising results, the proposed method has several limitations that need to be addressed in future research:

- **Ground Truth Dependency:** The current validation of the method is based on assumed ground truth data, which may not be accurate. In the future, the approach should be validated using annotated datasets to improve its reliability and real-world applicability.
- **Intensity Assumptions:** The method assumes that tumors are the brightest regions in the image, which may not always be the case, especially for tumors that are hyperintense or hypo-intense. Future work should explore adaptive thresholding techniques or alternative intensity-based segmentation methods to address this limitation.
- **Advanced Clustering Techniques:** While K-means clustering is effective, other advanced clustering techniques like fuzzy C-means or deep learning-based segmentation models may offer better performance, especially in images with complex intensity distributions or varied tumor characteristics.

- **Incorporation of Adaptive Thresholding:** To improve the segmentation performance under varying imaging conditions, future research could incorporate adaptive thresholding methods that can dynamically adjust based on the image characteristics.

6. Conclusion

This study demonstrates the effectiveness of K-means clustering combined with pre-processing and morphological operations for automated tumor segmentation. The proposed approach achieved high accuracy in tumor detection despite relying on assumed ground truth data. The results support the feasibility of using automated tumor segmentation methods in clinical practice and suggest potential improvements for handling more complex and diverse imaging scenarios. Future research will focus on validating the approach with annotated datasets and exploring advanced clustering techniques to further enhance segmentation accuracy and robustness.

Acknowledgment

This research was supported by Dr. Radhakrishnan, who provided invaluable guidance throughout the study. We also extend our gratitude to our colleagues at Don Bosco College for their expertise and contributions to this research.

References

[1] M. Reza, M. R. Mahdiraji, M. R. Mahmud, "Brain Tumor Segmentation Using K-Means Clustering and Deep Learning with Synthetic Data Augmentation for Classification," IEEE Access, 10, 45632 (2022).

[2] A. Sharma, P. Gupta, "Morphological Based Segmentation of Brain Image for Tumor Detection," Int. J. Biomed. Imaging, 15, 112 (2020).

[3] K. Patel, R. Shah, "Brain Tumor Segmentation Utilizing Thresholding and K-Means Clustering," J. Med. Imaging, 8(3), 245 (2019).

[4] L. Wang, T. Chen, "Brain Tumor Segmentation Using Morphological Processing and Discrete Wavelet Transform," Comput. Med. Imaging Graph., 42, 89 (2018).

[5] S. Kumar, V. S. Reddy, "MRI Brain Tumor Segmentation Using Hybrid Clustering and Morphological Operations," Med. Phys., 46(5), 321 (2021)