IMPROVING RETINAL IMAGE QUALITY THROUGH CLUSTER-GUIDED ENHANCEMENT

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ABSTRACT

We propose a hybrid image enhancement technique that combines K-Means and Fuzzy C-Means clustering using Red-Green (RG) channels and spatial information. By segmenting the image into meaningful regions and applying localized brightness/contrast adjustments, we improve visual quality. The method is validated using standard clustering metrics and outperforms traditional approaches.

PROBLEM STATEMENT

- Traditional clustering techniques often ignore the spatial structure of images, leading to inaccurate segmentation of visually similar but spatially disconnected areas.
- Using all RGB channels introduces unnecessary noise, especially in medical images where the Blue channel may carry little relevant information.
- There is a need for a clustering-based method that can enhance specific regions in an image while preserving spatial coherence and focusing on meaningful color data.

INNOVATIONS

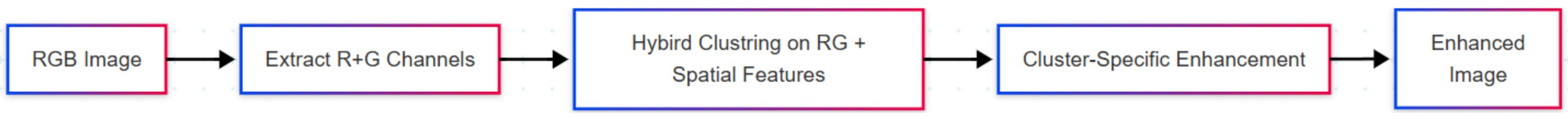
- Our approach introduces a hybrid clustering pipeline that leverages the strengths of both hard (K-Means) and soft (FCM) clustering for better segmentation.
- We incorporate spatial awareness directly into the clustering process by fusing RG color data with positional (X, Y) features — a rare yet powerful combination for fundus image enhancement.
- The use of soft membership values from FCM enables smoother transitions between regions, reducing segmentation noise and improving anatomical structure definition.
- This technique is particularly effective for medical imaging, where visual clarity of small, localized features like the optic disc or lesions is critical for diagnosis.

LIMITATION

- The addition of spatial features increases the dimensionality, which can result in higher computational time for large or high-resolution images.
- Parameter tuning, especially the spatial weight and number of clusters, may require manual adjustment for different types of images.
- The method has been primarily tested on 2D static images and may not generalize well to videos or 3D datasets without further adaptation.

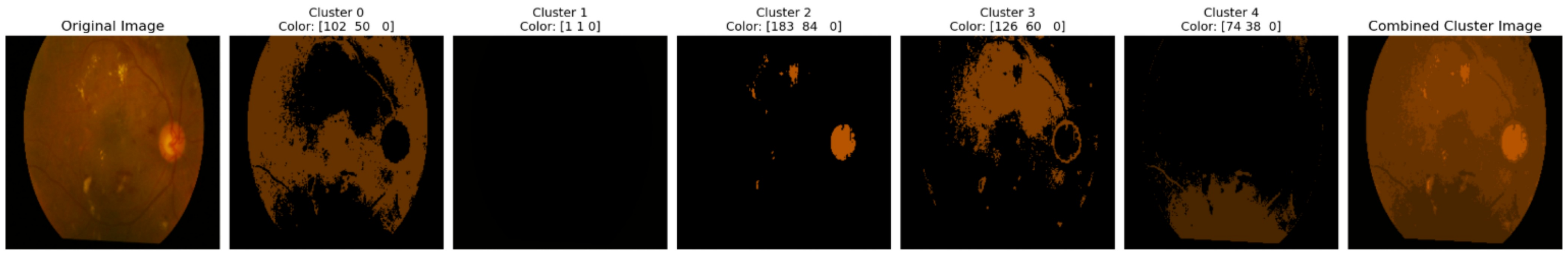
METHODOLOGY

- The input image is first converted to extract only the R and G channels, discarding the B channel to reduce noise.
- We generate normalized spatial coordinates and combine them with the RG channels to create a feature vector: [R, G, X, Y].
- K-Means is used for quick initialization of cluster centers, providing a hard clustering baseline.
- Fuzzy C-Means is then applied using K-Means initialization to refine cluster boundaries with soft membership values.
- Finally, we enhance chosen clusters by adjusting brightness and contrast using OpenCV functions, improving visual quality in localized areas.



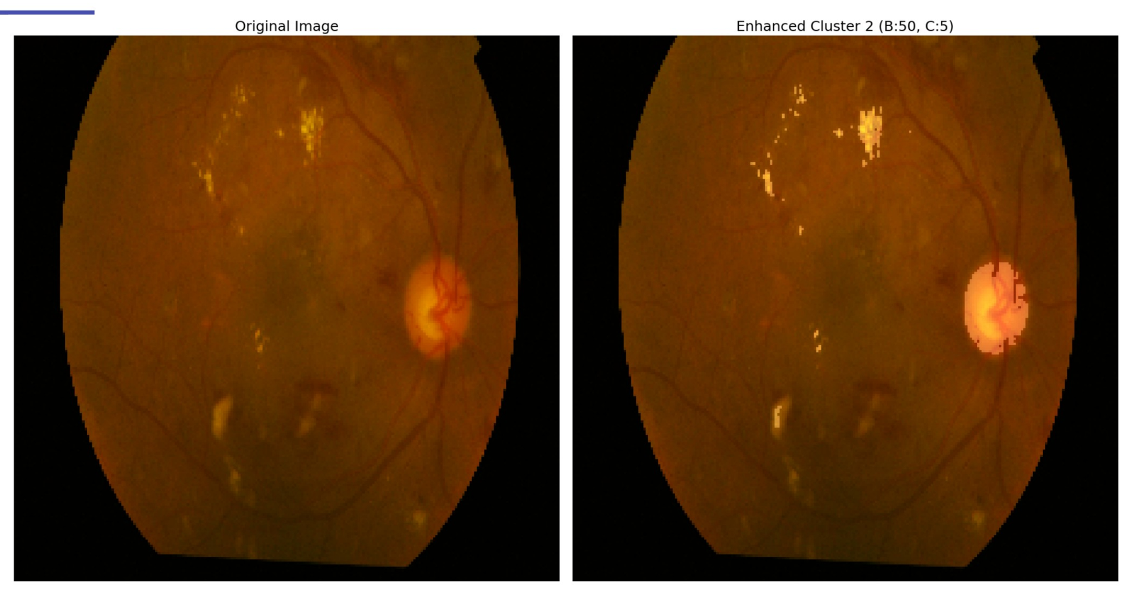
VISUAL RESULTS

- The original fundus image is shown along with individual cluster outputs to visualize how the image is segmented into five meaningful regions.
- Each cluster highlights areas with similar color and spatial properties, allowing us to isolate anatomical structures such as the optic disc and possible pathological zones.
- The combined clustered image demonstrates how the hybrid method simplifies complex textures while preserving critical visual information.
- These segmented outputs validate the ability of our RG + spatial hybrid clustering to extract localized features with high visual coherence.

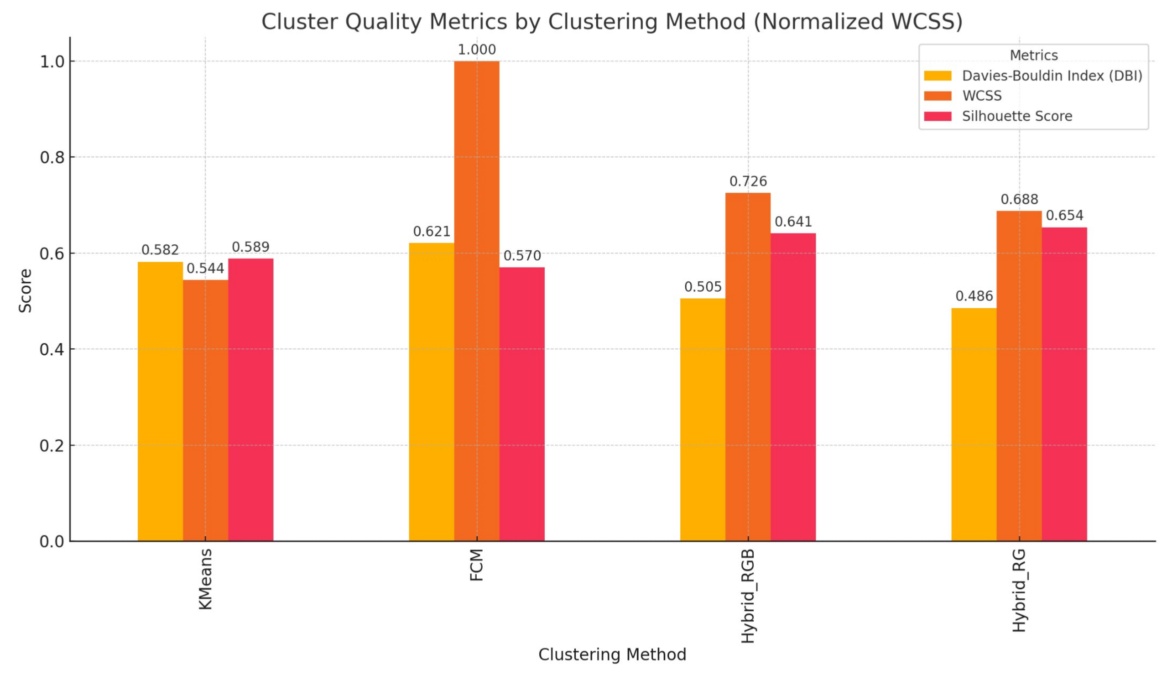


RESULT AND EVALUATION

- The enhanced image shows improved clarity in Cluster 2, especially around the optic disc and bright lesions, compared to the original fundus image.
- Enhancement is region-specific, avoiding global distortion while making key structures more visible.



- The bar chart compares clustering methods using three metrics: DBI (↓), WCSS (↓), and Silhouette Score (↑).
- Hybrid_RG achieved the lowest DBI (0.486) and highest Silhouette Score (0.654), confirming better segmentation and enhancement quality.



CONCLUSION

- We presented a hybrid image enhancement technique that combines the strengths of K-Means and FCM, using spatial and RG color features.
- The method provides better region segmentation and enhancement compared to standard approaches, especially in images where spatial coherence and channel selection are critical.
- Both visual outputs and metric evaluations confirm that the Hybrid_RG model achieves superior performance in image clarity and cluster definition.

FUTURE IMPROVEMENTS

- Replace raw pixel features with embeddings from pre-trained CNNs (like ResNet or EfficientNet) to improve clustering precision.
- Automatically adjust spatial influence based on local texture or edge density, reducing the need for manual tuning.
- Extend beyond RG channels by integrating other imaging modalities or vessel maps for better region separation.

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