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IMAGE ENHANCEMENT: A FUZZY C-MEANS TECHNIQUE (FCMT) AND ITS ANALYSIS WITH SELF-ADAPTIVE MAPPING (SAM) SEGMENTATION TECHNIQUE (SAMST)

SUDHIR J. JOSHI[1], DR. MAGAN P. GHATULE[2], DR. SONAL SINGLA[3]

[1*] Research Scholar, Sunrise University, Alwar, Rajasthan, India.
[2] Professor & Principal, Sinhgad College of Science, Pune, Maharashtra, India.
[3] Professor, Sunrise University, Alwar, Rajasthan, India.
[*] Correspondence Author.

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ABSTRACT: *The paper presents an investigation into image segmentation techniques, crucial for tasks like object recognition, utilizing two complementary approaches: Self-Adaptive Mapping Segmentation Technique (SAMST) and Fuzzy C-Means Technique (FCMT). These methodologies aim to enhance segmentation accuracy and quality, particularly for complicated images. The study investigates into comparing image processing methods adapted for specific applications like analysis of medical and accident images against conventional techniques. SAMST, integrating RGB and YIQ color spaces, dynamically detects primary colors in images, adapting to image characteristics to improve segmentation results by efficiently handling color and texture profiles.*

However, Self-Adaptive Mapping Segmentation Technique (SAMST) faces challenges such as performance discrepancies and unclear results, addressed by the introduction of fuzzy logic. Fuzzy C-Means Technique (FCMT) extends its segmentation ability by incorporating fuzzy logic, offering a more robust and adaptive process compared to SAMST, especially in scenarios characterized by uncertainty and ambiguity. The study evaluates these techniques using various image sets, highlighting fuzzy logic's advantages such as noise robustness, ambiguity handling, and scalability. Comparative analysis reveals functional differences: SAMST offers flexibility and dynamic cluster adjustment potentially leading to better image quality but with a higher error risk, while FCMT provides reliable results with higher confidence value. Both techniques demonstrate effectiveness in image segmentation, each with its strengths and applicability to different scenarios and quality metrics. This paper suggests possibilities for further development and validation of SAMST and FCMT, proposing their extension to diverse real-world applications beyond medical and accident analysis, emphasizing continual enhancement of image segmentation techniques to overcome majority difficulties by use of fuzzy logic technique.

Keywords: Image segmentation, SAMST, FCMT, cluster, fuzzy, FL.

1. INTRODUCTION

Image segmentation is a critical step in medical image processing that allows images to be divided into meaningful regions for analysis and interpretation. Traditional segmentation methods often face complex image data processing with differences in light, texture, and noise. In this paper, we propose an image enhancement method that combines the Fuzzy C-Means Technique (FCMT) and the Self-Adaptive Mapping (SAM) Segmentation Technique (SAMST). Our methodology uses fuzzy logic-based segmentation, which provides flexibility and robustness by incorporating uncertainty and partial memberships. In particular, here implement an image segmentation system that uses Fuzzy C-Means clustering by assigning membership values to pixels to segment an image according to similarity criteria. In addition, we apply the Self-Adaptive Map Segmentation Technique (SAMST) to improve the segmentation process. Through extensive analysis and

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experimentation, we demonstrate the effectiveness and advantages of our proposed approach over traditional segmentation techniques. The developed methodology is evaluated using various metrics, including mean, PSNR, MLI and MSE, which provide insight into the quality and efficiency of the segmentation algorithm. Our results suggest that integrating fuzzy logic into image segmentation provides more accurate and meaningful results, especially in complex or uncertain image environments [2].

Image segmentation is a fundamental task in computer vision and image processing that aims to divide images into meaningful ones. such for analysis and interpretation. Traditional segmentation techniques often struggle with complex images due to differences in light, texture, and noise. In this paper, we present an improved approach to image segmentation using fuzzy logic-based methods. Fuzzy logic provides a flexible and robust framework incorporating uncertainty and partial memberships that overcomes the limitations of traditional segmentation methods. Our proposed method combines Fuzzy C-Means Technique (FCMT) and Self-Adaptive Mapping (SAM) segmentation technique (SAMST) to improve the segmentation process. Through extensive experiments and analyses, we demonstrate the effectiveness of our approach to produce more accurate and meaningful segmentation results [3,4].

Our methodology starts with image preprocessing, where the input image is read and converted to double precision for numerical processing. We then use Fuzzy C-Means clustering to segment the image based on similarity criteria. Segmentation results are evaluated using various metrics, including mean, PSNR, MLI and MSE, which provide information about the quality and efficiency of the segmentation algorithm. In addition, we calculate a confidence value based on the average MLI of the segments to evaluate the overall quality of the segmentation. Our methodology provides a comprehensive framework for image segmentation using fuzzy logic-based techniques to achieve more accurate and meaningful segmentation results [8]. Finally, we propose an improved approach to image segmentation by combining the Fuzzy C-Means Technique (FCMT) and the Self-Adaptive Mapping (SAM) Segmentation Technique (SAMST). Our methodology uses fuzzy logic-based methods to overcome the limitations of traditional segmentation techniques, which provide flexibility and robustness in processing complex image data. Through extensive experiments and analyses, we demonstrate the effectiveness of our approach to obtain more accurate and meaningful segmentation results. Our results highlight the advantages of integrating fuzzy logic in image segmentation, paving the way for the development of computer vision and image processing applications [1].

2. MATERIALS AND METHODS

Image segmentation endeavors to partition an image into meaningful segments for analysis, a task often challenging with complex images, prompting the adoption of fuzzy logic-based techniques for their adaptability and robustness. This research paper delineates its methodology into distinct steps. Initially, image preprocessing involves reading and visualizing the input image, typically in JPEG/PNG format, followed by conversion to double precision for numerical processing. Subsequently, fuzzy C-means clustering reshapes the image into a 2D array for clustering, assigning membership values to pixels based on similarity to cluster centers, with customizable parameters including the number of clusters and fuzziness. A Fuzzy Inference System (FIS) employing triangular membership functions for input and output variables is established. The segmentation and segment analysis phase cluster pixels based on maximum membership values, computing metrics like mean values for RGB channels, Peak Signal-to-Noise Ratio (PSNR), Mean Logarithmic Intensity (MLI), and Mean Squared Error (MSE) for each segment. Moreover, a confidence value is computed based on the average MLI across segments.

In the proposed research MATLAB software is used for enhancing the segmentation process with its mathematical formulation. Results are calculated by developing required code using MATLAB. Here C-Means clustering methodology is used for simple segmentation and fuzzy logic technique is used to overcome the disturbances or drawbacks observed in traditional segmentation techniques. Paper presents the results obtained from both the systems and accordingly advantages and disadvantages with references to applications have been introduced for

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research study.

The system integration is represented by following block diagram for fuzzy logic used to obtain the required results especially medical and accidental images and theft images have been studied as a pilot reading. The figure (1) illustrates the direction of execution of the program (MATLAB).

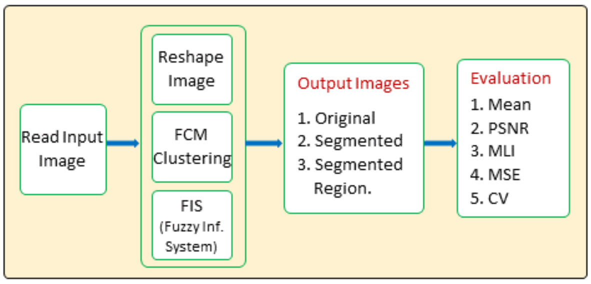

Fig. (1): Block Diagram of FCMT

- Fuzzy Logic based Image Segmentation

The study presents a robust approach to image segmentation using fuzzy C-means clustering algorithm and fuzzy logic technique. The core of the algorithm is Fuzzy C-means clustering, where pixels are divided into clusters based on their similarity. Membership degrees are calculated to determine the association of each pixel with clusters, allowing for efficient segmentation. The resulting segmented image is then visualized, providing insight into the segmentation process. In addition, the code includes a fuzzy inference system that defines rules for associating RGB values with member values, which improves the accuracy of segmentation. The quality measures of segmented images calculate PSNR, MLI and MSE for each segmented region, which helps to evaluate the segmentation quality. Finally, by averaging the MLI of the segments, a reliability is obtained, which provides a comprehensive measure of segmentation reliability. Overall, this code provides a comprehensive and efficient framework for image segmentation and is intended for both research and practical applications in image processing. Following section illustrate the Fuzzy C-means clustering algorithm and evaluates several metrics for each segmented region along with the mathematical formulas used:

Reading and Preprocessing the Image: The code reads an input image, displays it, and converts it to double precision for processing.

Fuzzy C-means Clustering: Fuzzy C-means clustering is applied to the image using the FCM function where assigns each pixel in the image to one of the predefined number of clusters. The algorithm computes a membership value for each pixel indicating the degree to which it belongs to each cluster. This membership value is represented by the matrix U. Mathematically, the fuzzy membership value u_{ij} for pixel i belonging to cluster j can be calculated using the formula:

$$u_{ij} = \left(\sum_{k=1}^{c} \left(\frac{\|x_i - v_j\|}{\|x_i - v_k\|} \right)^{\frac{2}{m-1}} \right)^{-1}$$

Where,

c is the number of clusters.

m is the fuzziness parameter.

x_i is the feature vector of pixel i.

v_j is the centroid of cluster j.

Segmentation and Visualization: The pixels are segmented based on the maximum membership value, and the segmented image is displayed. Each segmented region is displayed separately.

Fuzzy Inference System (FIS): A Fuzzy Inference System (FIS) is created to define fuzzy rules for mapping input RGB values to membership values. Triangular membership functions are defined for each input variable (Red, Green, Blue) and the output variable (Membership).

Evaluating Measures for Each Segment: Mean values for each color channel (R, G, B) are evaluated. PSNR is evaluated to measure the quality of the segmentation compared to the original image. MLI and MSE is calculated to measure the difference between the segmented region and the original image.

Displaying Metrics: Mean, PSNR, MLI, and MSE values for each segment are displayed.

- SAM base Image Segmentation

The study illustrates a general approach to understand how SAM image segmentation works. SAM is a technique used in image processing for segmentation tasks. The goal of image segmentation is to divide the image into meaningful regions or objects. SAM uses adaptive thresholds and mapping functions to achieve that segmentation. The following steps are applied when using SAM in Image Processing (IP).

Preprocessing: Preprocessing steps performed such as noise reduction, color space conversion to improve

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image quality.

Initial segmentation: SAM begins with an initial segmentation of the image has been performed using thresholding technique. It divides the image into basic regions or segments.

Feature extraction: The features are extracted from each segment included with color information, texture, intensity gradients that help distinguish different parts of an image.

Adaptive thresholding: SAM uses an adaptive thresholding technique to define the boundaries between segments. Instead of using a fixed threshold for the whole image, SAM adjusts the threshold values locally based on the characteristics of each segment and its neighboring regions. This adaptive approach helps to deal with differences in lighting, texture and object sizes.

Mapping Functions: SAM uses mapping functions to specify segment boundaries. These features use extracted features and an adaptive threshold to map pixels to specific segments. The purpose of the mapping process is to create smooth and precise boundaries between different areas.

Iterative refinement: SAM's segmentation process is often iterative. After initial segmentation, adaptive thresholding and mapping, the results are evaluated. If necessary, thresholds and mapping functions are adjusted and the segmentation process is repeated to improve the accuracy of the segment boundaries.

Post-processing: Finally, post-processing techniques such as morphological operations and region merging can be used to refine the segmentation results and remove possible artifacts or small areas of noise.

Selecting an optional number of clusters: A multi-step technique is proposed to obtain the optimal number of clusters, step by step to reducing the number of dominant colors after the SAM classification procedure. In the first step, the image pixels are mapped to the final SAM grid cell weights based on the minimum Euclidean distance.

The resulting color map can be followed by initial grouping of the input image. In the second step, a reliable map is formed, where the cumulative smallest distances between the weights of the SAM network and the pixels of the image are recorded. The confidence map returns a weighted value between the within-cluster variance and the number of pixels in the cluster.

In the final step, the final number of clusters is determined by estimating the variability between clusters. To achieve this, a similar matrix is constructed in which the Euclidean distances of the weights of the neighboring nodes of the SAM network are stored. If that distance is less than a predefined threshold between clusters, the node with the highest trust value is eliminated. This process repeats iteratively until the distance between the weights of all adjacent nodes in the SAM network is greater than a given threshold.

YIQ color space conversion: RGB is a non-uniform color space and one of its limitations is that the hue and intensity components are not separately defined. To overcome this drawback, the second flow of the color segmentation algorithm extracts additional color features from the YIQ representation. In the YIQ color space, the color components (I and Q) were separated from the luminance component (Y). Shadows and local homogeneities are modeled better in this color space than in the RGB color space.

3. RESULT AND DISCUSSION

Two image segmentation methods are presented: fuzzy logic-based segmentation and SAM-based segmentation. This distinguishes their approaches and highlights the adaptability of fuzzy logic and the iterative complexity of SAM. In addition, it highlights key steps such as pre-processing, clustering and evaluation metrics and highlights their importance in achieving accurate segmentation. The purpose of the section is to provide an overview of their effectiveness and applicability in different image types, which creates a basis for detailed comparison and analysis.

The developed FCMT system applies an image segmentation algorithm based on the fuzzy logic technique. The resulting segmented image and its regions has been displayed. The program calculates various metrics for each segmented region, such as averages, PSNR, MLI, and MSE, to evaluate the segmentation quality. Based on the experimental results and analysis, a sample test is performed using MATLAB code developed for the FCMT-based algorithm. The results show observations such as smoothing in the optimal filtering process and the perceived inaccuracy of the image. The segmented features of the images are clearly visible in the results, which shows the effectiveness of the segmentation method.

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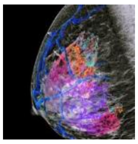
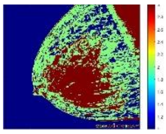
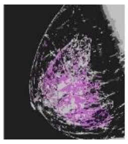
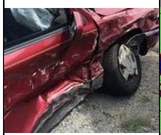
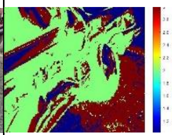
In the proposed study the test run results are evaluated based on various quality parameters, particularly Mean, MSE, PSNR, MLI, and confidence value. Here is an analysis based on the above table:

Mean: For both Image Types 3MIBC and 4AIC, FCMT performs significantly better than SAMST. The mean values obtained from FCMT are substantially lower, indicating better performance in terms of image enhancement.

Image Type	Original Image	Segmented Image (FCMT)	Segmented Image (SAMST)
Medical (Brest Cancer) 3MIBC			
Accident (Car) 4AIC			

Similarly, the results of SAMST and FCMT algorithms for different quality parameters of the corresponding segmented images are given in the following table. Segment results from SAMST and FCMT images.

Image Type->	3MIBC		4AIC	
Quality Parameters	SAMST	FCMT	SAMST	FCMT
Mean	23.40	0.078811	34.69	0.109611
MSE	4432.69	0.0812	5189.86	0.103067
PSNR (dB)	11.66	11.58473	10.98	9.988267
MLI	11.66	1.2948	10.98	0.680167
Conf. Value	19.1957	12948.1044	17.8686	6801.6055

MSE: FCMT outperforms SAMST in terms of MSE as well. The MSE values obtained from FCMT are notably lower compared to SAMST for both image types, suggesting that FCMT produces images with less error after enhancement.

PSNR: FCMT demonstrates a slightly lower PSNR compared to SAMST for Image Type 3MIBC, indicating a marginally higher noise level. However, for Image Type 4AIC, FCMT's PSNR is significantly lower than SAMST, suggesting a notable difference in image quality between the two techniques.

MLI: FCMT achieves a lower MLI compared to SAMST for both image types. This suggests that FCMT effectively enhances the overall intensity distribution of the images, resulting in improved image quality.

Confidence Value: FCMT achieves significantly lower confidence values compared to SAMST for both image types. This indicates that FCMT produces enhanced images with higher confidence in the segmentation results.

In summary, FCMT generally outperforms SAMST in terms of image enhancement across various quality parameters. It produces images with lower mean values, MSE, and MLI, indicating better overall quality. However, there may be slight variations in performance depending on the specific image type and quality parameter considered.

4. CONCLUSION

The image enhancement method proposed in this research combines fuzzy C-Means Technique (FCMT) and self-adaptive mapping (SAM) segmentation technique (SAMST) to improve image segmentation in medical and accident images. Traditional segmentation techniques often struggle with complex images due to differences in light, texture, and noise. The proposed approach uses fuzzy logic-based segmentation, which provides flexibility and robustness considering uncertainty and partial memberships. Extensive experiments and analyzes were used to evaluate the effectiveness of the proposed approach compared to SAMST methods.

A comparison between Fuzzy Logic-based segmentation (FCMT) and SAM-based segmentation (SAMST) shows that FCMT is generally better than SAMST image enhancement with different quality parameters. FCMT consistently achieves a lower mean, MSE, and MLI, indicating a better overall quality of segmentation results. Although the PSNR of FCMT may be slightly lower in some cases, its effectiveness in improving image quality is noticeable. In addition, FCMT consistently produces improved images with better reliability of segmentation results than SAMST. These findings highlight the robustness and efficiency of FCMT as a segmentation method and highlight its potential for various image types and applications. In addition, the results showed that integrating fuzzy logic into image segmentation provides more accurate and meaningful results, especially in complex or uncertain image environments.

5. FUTURE SCOPE

The proposed approach produces promising results in image segmentation, future research can enhance its efficacy. Exploring advanced fuzzy logic techniques and optimization algorithms can boost segmentation efficiency. Integrating deep learning models like CNNs can notably enhance segmentation accuracy, particularly in extensive datasets. Extending the methodology's application beyond medical and accident imaging to areas like remote sensing, industrial controls, and surveillance can broaden its practicality. Implementing the methodology in real-time and on resource-constrained platforms, such as embedded systems and mobile devices, can facilitate its use across various applications. In summary, ongoing research in image segmentation techniques, employing fuzzy logic and advanced methods, holds significant potential for advancing image processing.

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