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Image Enhancement Using Local and Global Features Optimization

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Abstract. *Image enhancement involves techniques employed to improve the digital quality of images, particularly those of poor quality. One specific method discussed is contrast enhancement, which aims to produce clearer images by redistributing brightness intensity values. This enhancement process utilizes feature optimization techniques, notably particle swarm optimization, to effectively select both local and global features of an image. The optimized features are then applied across the entire image, resulting in improved quality. Experimental results indicate that the proposed threshold-based enhancement algorithm for mixed digital images performs better than traditional methods, especially in cases with heavily damaged pixels, demonstrating its effectiveness in complex scenarios.*

Keywords: Image features, PSO, Histogram, Brightness, Contrast.

Introduction

Image detail upgrade calculations play a crucial role in enhancing the visual quality of pictures by improving subtle details while avoiding common issues such as glare artifacts and edge inversion artifacts. The process typically involves decaying a source image into a base layer of homogeneous regions with sharp edges and a detail layer containing fine details or textures using edge-preserving decomposition algorithms. Resultantly, a detail-enhanced image is produced, remapping the pixel values to amplify contrast and detail over the original image, thus enriching aesthetic appeal and aiding in functions like image segmentation, analysis, and feature extraction. In practical applications, various image enhancement techniques must satisfy specific demands depending on context, such as in photography, object detection, optical character recognition (OCR), and particularly in medical imaging, for instance, mammographic image enhancement and denoising, which are vital for early breast cancer detection. The critical improvement needed in mammography involves enhancing contrast to differentiate between abnormal and normal dense tissues, often not perceptible to the human eye, thereby providing radiologists with superior images to work with. Several image enhancement methodologies have been proposed, though many are not directly applicable to mammograms due to their textured nature, complicating appropriate enhancements. Methods like adaptive un-sharp masking have also been employed but fall short in recognizing low contrast edges, such as micro-calcifications in mammograms. Research has focused on enhancing contrast in mammograms, particularly for identifying image elements relevant to breast cancer detection, employing adaptive local methods that, while improving mammographic features, remain susceptible to noise and can introduce artifacts. Rangayyan and colleagues explored contrast enhancement in mammography, attempting to balance enhancement effectiveness with the preservation of original image integrity. Their adaptive local contrast enhancement (ANCE) method highlights the sensitivity of breast cancer diagnosis by improving contrast without significant loss of the original image quality, while alternative wavelet-based methods provide improvement at the risk of increased noise, thereby indicating the ongoing challenges in the domain of image enhancement for mammographic applications.

Optimization of features for image enhancement requires a careful balance of local and global features. Local features capture fine details, while global features provide context and structure to the image. The integration of both types enhances the overall quality of image processing by improving clarity, sharpness, and detail retention. Techniques such as histogram equalization, contrast stretching, and the use of advanced algorithms play vital roles in refining image quality. The study emphasizes the need for algorithms that effectively merge these features to achieve superior results in various imaging applications.

Problem statement

- The goal is to estimate an uncorrupted (enhanced) image from a noisy or distorted input image.
- Existing enhancement methods are often specialized and may not generalize well across different image types (e.g., satellite vs. medical).
- Simple smoothing techniques like mean filtering or neighborhood averaging reduce noise but cause blurring, losing edge details.
- There's a need for an algorithm that balances noise removal, feature preservation, and contrast enhancement.

Proposed Work

In this paper, a novel image enhancement technique utilizing Particle Swarm Optimization (PSO) is proposed. PSO is defined as a dynamic, population-based optimization method where each pixel value is treated as a particle. The approach measures pixel value similarity based on the velocity of difference values, categorizing a difference value of zero as standard data, while non-zero values indicate noise or degraded areas of the image. The discussion transitions through various concepts including the LGE (Local Gradient Enhancement) algorithm for image enhancement and the application of PSO within this context. The LGE function organizes all data into a matrix channel format from which image features are extracted. PSO is implemented as a clustering mechanism that projects N-dimensional features derived from the LGE function into an M-dimensional feature space. This methodology involves classification of these vectors through a PSO framework, designed to categorize them into predefined classes of damaged pixel values. The proposed scheme integrates the particle swarm algorithm to facilitate the collection of local intensity data from the image, merging damage pixel values with high-intensity image values to create new vector values for processing.

As the PSO algorithm operates, it crafts a trajectory of winner nodes for specific words, learning from the constraints associated with each damaged pixel. Inputs received from the LGE function bank are mapped to form an M-dimensional space, where the dimensionality aligns with the distribution of PSO output nodes. This leads to the generation of a primary feature space through the LGE function's output and a secondary feature space derived from the processing of these features by the PSO, resulting in secondary feature vectors. Together, these components articulate a comprehensive framework for effective image enhancement through the collaborative mechanism of PSO and LGE methodologies. This research work, outlines a multi-step process for image enhancement using a Particle Swarm Optimization (PSO) algorithm. The first step involves inputting an image which is then decomposed into its constituent channels via a LGE function. Each channel measures varying intensity values, from which lower intensity values are collected to inform the PSO algorithm. In the subsequent steps, the PSO algorithm identifies local damage pixels and combines these with higher intensity values to form a comprehensive dataset of damaged pixels. This compilation is then converted into a feature vector, which is passed through a self-filter. During the feature mapping phase, the PSO network creates fixed clusters in the feature space based on image detail thresholds. The procedural steps for employing the PSO algorithm include initializing each pixel as a particle, selecting a random vector within the PSO context, measuring the velocities between particles, and calculating the neighborhood around the global best solution (Gbest). The neighborhood's size decreases with each iteration, refining the search for optimal solutions. Calculations for the personal best (Pbest) are performed based on the Euclidean distance between pixels, thus providing an effective measure of similarity between datasets. This iterative process continues until convergence is achieved. After processing, the output image undergoes further enhancement, culminating in a resultant image that is evaluated using the Peak Signal-to-Noise Ratio (PSNR) as a measure of quality. Overall, the document provides a detailed description of the PSO algorithm's role in enhancing image quality through specific procedural and mathematical steps.

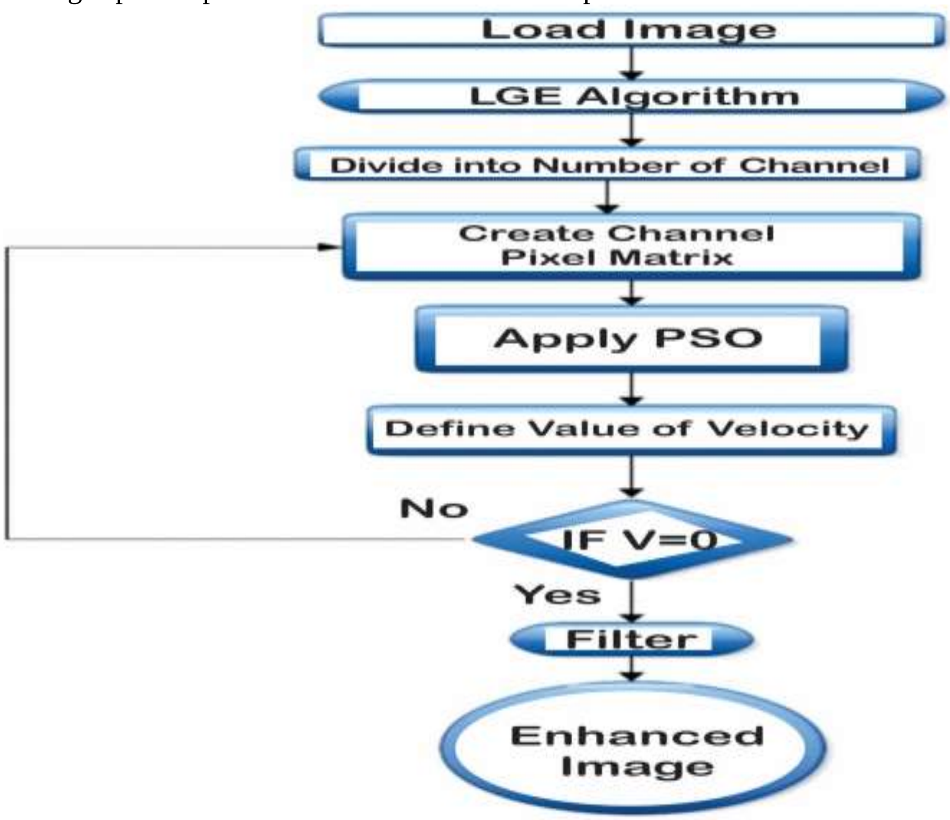

Figure 1: Proposed model work flow using PSO algorithm.

Result Analysis

Implementation was performed using MATLAB 7.8.0 on various image datasets, including standard test images like 1.jpeg and barbara.jpeg. The performance of the proposed method was compared against the traditional LGE method using metrics such as:

- Brightness Histogram (BH)
- Contrast Histogram (CH)
- Signal-to-Noise Ratio (SNR)
- Peak Signal-to-Noise Ratio (PSNR)

Visual and quantitative results demonstrated that the proposed PSO-based hybrid method outperformed traditional methods, especially in: Handling images with more damaged pixels, Enhancing complex image regions with mixed noise, Iimproving overall clarity and contrast, Graphs comparing BH and CH for both test images showed better distribution and enhancement in the proposed method.

IMPORTED IMAGE – 1		
METHOD	BH	CH
Existing	34.4562	20.1256
Proposed	14.3715	37.1765

Table 1: Presents a comparative analysis of loading a 1.jpeg image using the existing and the proposed method in the context of optimizing features for image enhancement through local and global features.

IMPORTED IMAGE - Barbara		
METHOD	BH	CH
Existing	28.5642	17.35
Proposed	13.356	30.26

Table 2: Presents a comparative analysis of loading a barbara.jpeg image using the existing and the proposed method in the context of optimizing features for image enhancement through local and global features.

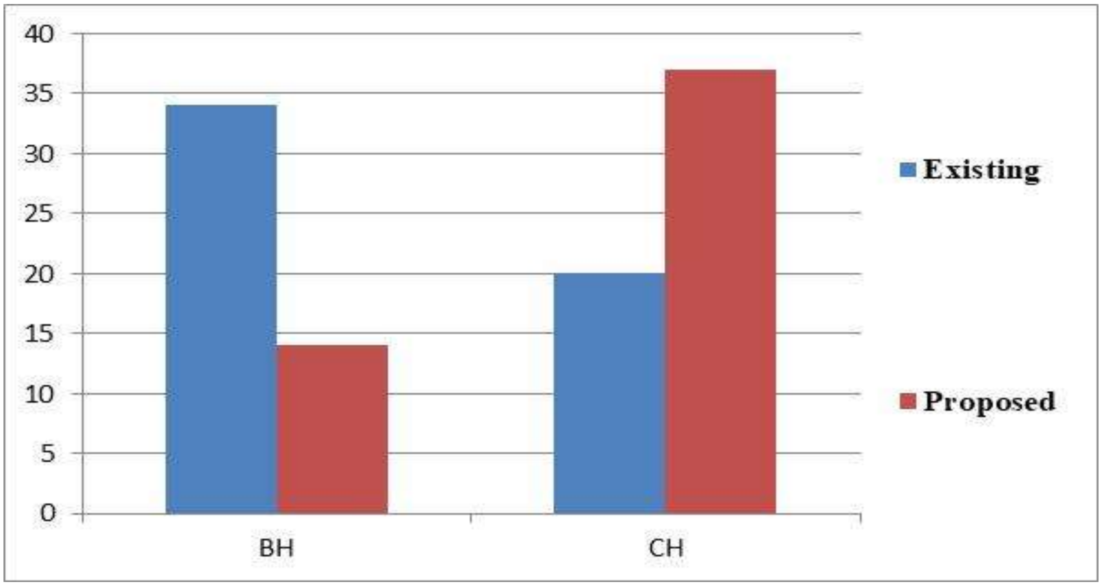

Figure 2: Illustrates the comparative results of using the BH and CH metrics for loading a 1.jpeg image via the existing and proposed method in the context of optimizing features for image enhancement, utilizing both local and global features.

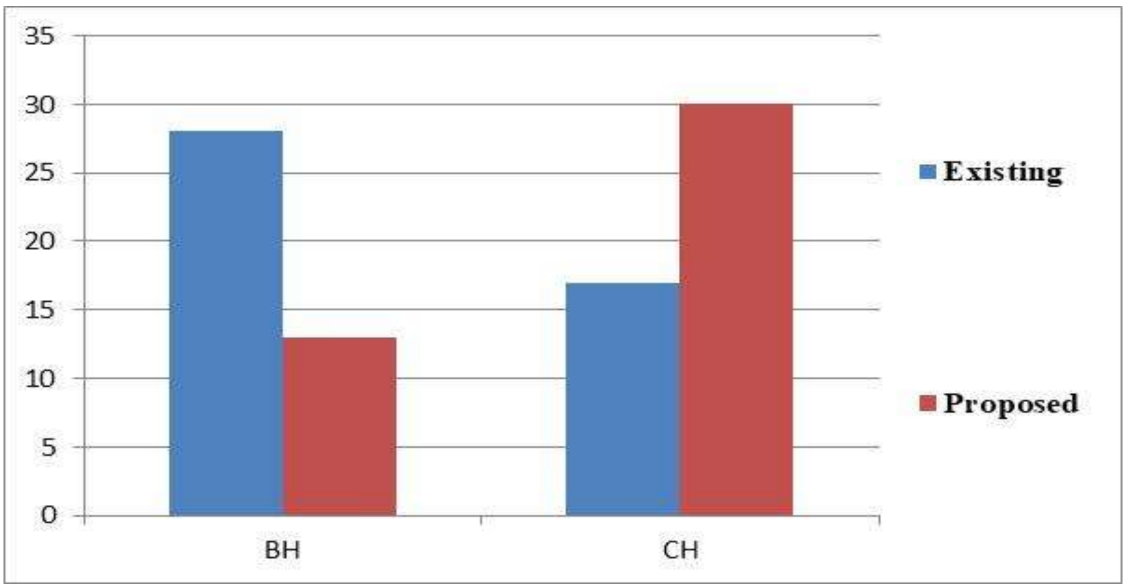

Figure 3: Illustrates the comparative results of using the BH and CH metrics for loading a barbara.jpeg image via the existing and proposed method in the context of optimizing features for image enhancement, utilizing both local and global features.

Conclusion

This research work, presents a novel image enhancement technique that combines local and global feature extraction through LGE with the optimization capabilities of PSO. This hybrid approach demonstrates superior performance in enhancing images corrupted by noise or damage, especially in complex scenarios with mixed pixel intensities. Despite the improved enhancement quality, the method incurs higher computational costs, which are addressed as future work through optimization techniques, this research work demonstrate proposed method gives better results than existing method, in future may implement with machine learning or deep learning model.

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