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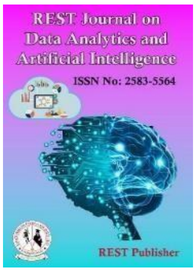

Advancements in Image Enhancement: Comparing Spatial and Frequency Domain Methods Using COPRAS Analysis

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Abstract: *Image enhancement is a fundamental process in the field of computer vision and digital image processing, aimed at improving the quality and visual appeal of images for various applications. This abstract provides an overview of key concepts, techniques, and applications in image enhancement. Image enhancement techniques can be broadly categorized into two main approaches: spatial domain and frequency domain methods. In the spatial domain, image enhancement is performed directly on the pixel values of the image. Common spatial domain techniques include contrast adjustment, brightness correction, histogram equalization, and filtering operations like sharpening and smoothing. These methods are effective for enhancing image details and reducing noise. Frequency domain techniques. In the frequency domain, it becomes possible to manipulate the image's frequency components, allowing for operations like filtering out specific frequencies to remove noise or enhance certain features. Frequency domain methods are particularly useful in applications like image denoising and compression. Image enhancement is a critical area of research in various fields, including computer vision, image processing, and computer graphics. Its significance stems from its ability to improve the visual quality of images and make them more suitable for various applications. In the field of medical imaging, image enhancement plays a vital role in improving the visibility of important details in X-rays, MRIs, and other medical images. This can aid in the early detection of diseases and enhance the accuracy of medical diagnoses. The COPRAS-G method requires identifying selection criteria; evaluating information related to these criteria, and developing methods to evaluate Meeting the participant's needs Criteria for doing in order to assess the overall performance of the surrogate. Decision analysis involves a Decision Maker (DM) Situation to do consider a particular set of alternatives and select one among several alternatives, usually with conflicting criteria. For this reason, the developed complexity proportionality assessment (COPRAS) method can be used. From the result Red channel is got the first rank whereas the fusion based is having the lowest rank.*

Keywords: *Image enhancement, image smoothing, noise removal, nonlinear filtering. Adaptive filters, image enhancement, UN sharp masking*

1. INTRODUCTION

Numerous modern techniques for improving image quality and detecting edges share similarities with an early concept introduced by Dennis Gabor. Dennis Gabor, renowned for his groundbreaking work in optical holography, as well as the introduction of Gabor functions in communication theory, is most widely recognized for these contributions. His pioneering work served as the inspiration behind the development of Gabor filters, which have greatly advanced the field of image enhancement. Gabor filters, a group of linear filters, excel at eliminating textural elements and edge information from images. They find widespread application in computer vision and image processing tasks. Gabor filters allow for the enhancement of image textures and edges while suppressing noise and unimportant features by examining the frequency and orientation characteristics of different image regions. Consequently, they play a crucial role in various applications such as face recognition, texture analysis, and fingerprint recognition. Dennis Gabor's work has left a profound impact on image enhancement, providing a powerful tool for improving the quality of visual data and identifying vital features across a wide range of applications in image analysis and computer vision. [1] We evaluated the performance of this image enhancement approach by comparing the accuracy of an online fingerprint verification system with the quality index of the extracted minutiae. Our experimental results indicate that the application of the enhancement algorithm leads to increased verification accuracy and an improved quality index. Fingerprint identification, a prominent biometric technology, has garnered considerable attention recently. Each fingerprint is unique, characterized by a pattern of ridges and valleys on the fingertip's surface, also referred to as furrows in fingerprint literature. The distinctiveness of a fingerprint is primarily defined by the local ridge characteristics and their interactions. There exist 150 distinct local ridge characteristics, including islands, short ridges, and enclosures, among others. However, the distribution of these regional ridge characteristics is not uniform and heavily depends on various factors, including the conditions during fingerprint acquisition and the overall quality of the fingerprint.[2] In the field of image processing, picture enhancement holds a pivotal role in elevating the quality of images. Its purpose is to highlight relevant information while reducing extraneous details. One of the most significant advancements in image processing is image enhancement, which strives to improve image quality for specific applications. In essence, the core concept behind image enhancement is to modify an image's content to make it better suited for a particular purpose. Conventional picture enhancement techniques primarily operate in two domains: the frequency domain and the spatial domain. Spatial image enhancement involves the direct manipulation of the image's pixels. Common methods in this category include traditional histogram adjustments and enhanced unsharp masking techniques [3].Digital image enhancement involves the use of computer-based techniques and algorithms to improve the visual quality of a digital image. This process aims to emphasize fine details and enhance the overall aesthetics of the image, often by making adjustments to factors like brightness, contrast, color balance, and sharpness. It seeks to bring out subtle or unnoticed aspects of the image, correct imperfections, and tailor it for specific applications such as video processing, medical imaging, photography, or remote sensing. These enhancement methods range from simple techniques like histogram equalization to more complex procedures that involve noise reduction, image filtering, and advanced image processing algorithms. In industries such as medical diagnostics, entertainment, surveillance, and scientific research, where clear and precise visual information is crucial for decision-making and analysis.[4]The process of adaptive unsharp masking is employed to enhance the visual appeal of digital photographs. This technique sharpens the image by emphasizing high-frequency elements while preserving low-frequency details. What sets it apart from traditional unsharp masking is its adaptability. Adaptive unsharp masking dynamically adjusts the sharpness intensity based on local image characteristics instead of applying a fixed filter to the entire image. Consequently, regions with more pronounced edges or intricate details will receive more intense sharpening, while smoother areas will remain largely unaffected. In image processing and enhancement, Adaptive Unsharp Masking serves as a valuable tool, as it customizes the sharpening process to the specific content of the image, resulting in enhancements that are both more aesthetically pleasing and natural in appearance.[5]Underwater image enhancement has attracted considerable attention due to its significance in marine engineering and aquatic robotics. In recent years, various techniques have been proposed to enhance underwater images. However, these methods are frequently assessed using either synthetic datasets or a limited selection of carefully chosen real-world photos. Consequently, it is challenging to predict their performance on photos taken in natural, uncontrolled settings and establish criteria for success in the field. To address this gap, we present the initial comprehensive perceptual investigation and analysis of underwater image enhancement, utilizing a large collection of real-world photographs. We introduce an organized evaluation system known as the "Underwater Image Enhancement Benchmark" in the field of underwater image processing and computer vision. This benchmark is a vital tool for evaluating and comparing the effectiveness of different algorithms and techniques aimed at improving the quality of underwater images, which are often plagued by issues such as poor visibility, color distortion, and noise. The benchmark comprises a diverse dataset of underwater images captured under various conditions and incorporates well-defined evaluation metrics that assess aspects like image sharpness, contrast, color accuracy, and noise reduction. Researchers and developers leverage this benchmark to objectively assess the performance of their image enhancement methods, facilitating equitable comparisons and progress in the advancement of technologies for applications like marine biology, underwater archaeology, and underwater surveillance [6].Fuzzy logic-based image enhancement seeks to address three seemingly contradictory objectives: reducing impulse noise, preserving non-impulse noise, and enhancing or preserving edges and prominent structures. In this approach, the adjustment of pixel gray-level values can be likened to noise filtering based on the surrounding context. The optimal filtering method should adapt to the local conditions at each pixel. For example, if the local region exhibits some degree of smoothness, the new pixel value may be an average of the neighboring values. Conversely, a different filtering approach is warranted when the local area includes edges or impulse noise pixels. Defining clear conditions for choosing a specific filter is an exceptionally challenging, if not impossible, task, as the local conditions in certain parts of an image can be vague. Consequently, a filtering system needs to be capable of making decisions based on uncertain and ambiguous input.[7]Expanding the definition of peer groups to encompass both color and multi-spectral images is straightforward. Instead of using intensity values in grayscale photos, we employ 3D color vectors for color pixels. The similarity between two colors can be assessed by measuring the Euclidean distance between their vectors. The peer group is determined based on the degree of similarity among the colors.To adapt the PGA technique described earlier for color images, we make two minor modifications. Firstly, we identify potential noisy pixels by comparing the variations in the distances (di). The size of the peer group is not estimated using these noisy pixels.[8].This approach employs a bilateral grid, a multi-dimensional data structure, to efficiently capture and manipulate the spatial and tonal information in an image. By integrating convolution neural networks (CNNs) with this bilateral grid framework, the method can enhance images by preserving important details while effectively reducing noise and artifacts. This combination of deep learning and bilateral filtering not only produces high-quality enhancements but also performs these enhancements rapidly, making it suitable for applications where real-time image processing is crucial. Whether in photography, video streaming, or medical imaging, this approach significantly improves the visual quality of images while maintaining a responsive and efficient processing speed [9]The MSRCR calculation differs from other automatic image enhancement techniques in two significant ways. First, unlike existing methods that rely on a single Look-Up Table (LUT) to explain the relationship between an image and its MSRCR-enhanced output, MSRCR operates as a nonlinear contextual operation. This means that the resulting representation of a specific input value varies depending on the surrounding pixels. Second, while previous automatic image processing methods adapt their transformations based on the image's content, leading to substantial variations in the LUT across different images, MSRCR employs canonical scales, weights, gains, and offsets that remain consistent across all images. In contrast, even the "autolevels" method, which uses a predetermined parameter as a percentage of total pixels but still adjusts its values for each image, shares this characteristic.[10]Methods for improving the visual quality of digital images fall within the realm of transform-based image enhancement algorithms. These algorithms utilize mathematical transformations like the Fourier transform and wavelet transform to examine and manipulate image data in different frequency domains. By disassembling an image into its constituent frequency components, these algorithms enable the targeted enhancement of specific features or details, such as edges or textures.To assess and compare these algorithms, various performance metrics are employed. In contrast, SSIM takes into account structural, contrast, and brightness aspects when evaluating how similar the original and enhanced images are.MOS, on the other hand, is a subjective metric that can only be determined through human assessments, which may be time-consuming but yield valuable insights into how well the enhanced images are perceived. These performance metrics are valuable tools for academics and engineers who need to assess and fine-tune transform-based image enhancement algorithms for a variety of applications, including medical imaging, photography, and computer vision [12].Genetic algorithms are a computational technique used for optimizing image enhancement processes. These algorithms are inspired by the principles of natural selection and evolution, and they work by iteratively evolving a population of potential image enhancement solutions to find the best one. In the context of image enhancement, genetic algorithms can be employed to adjust parameters like brightness, contrast, and color balance to enhance the visual quality of images. They do this by generating a diverse set of image enhancement possibilities and iteratively selecting and modifying the most promising ones. This approach allows genetic algorithms to discover optimal image enhancements, making them valuable tools in fields like computer vision, remote sensing, and medical imaging, where improving image quality is crucial for accurate analysis and interpretation [13].The enhancement of images through shock filters involves the utilization of new nonlinear, time-dependent partial differential equations, along with their corresponding discretization methods. This filtering procedure entails the transformation of the original image, denoted as u0(x, y), over time (as t approaches infinity) into a stable state solution, u∞(x, y), through the evolving function u(x, y, t) for t>0. The solutions to these partial differential equations adhere to the maximum principle. Additionally, at any given time t greater than zero, the total variation of the solution remains equal to the initial data. The zeros of the edge detector operator (which is an elliptic operator) correspond to the points where abrupt changes or jumps occur in the processed image. The algorithm exhibits piecewise smoothness and lacks oscillations. Furthermore, it is characterized by a rapid execution speed and simplicity in terms of programming, as outlined in reference [14].An enhancement to the median filter that enhances the significance of values falling within the range of is known as the (WM) filter. This wm filter presents a promising approach for enhancing image quality as it allows users to customize the degree of smoothing by adjusting the weights assigned to specific values. In this investigation, our focus is on the (CWM) filter, which represents a specific instance of WM filters. This particular filter offers a more straightforward development and application compared to standard WM filters since it simply prioritizes the central value within the window by assigning it additional weight. We will analyze the characteristics of CWM filters and discover that, when compared to other non-adaptive filters designed to preserve details, CWM filters excel in retaining more fine-grained features while trading off some noise reduction.[15]

2. MATERIALS AND METHOD

2.1Fusion-based: Fusion-based image enhancement is a technique used to improve the quality and visual appearance of an image by combining information from multiple source images. It's particularly useful in scenarios where a single image may not provide enough information to produce a high-quality result, or where different source images contain complementary information.

2.2Two-step-based: Two-step-based image enhancement is a method that involves a two-stage or two-step process to improve the quality and visual characteristics of an image. This approach typically divides the enhancement process into two distinct steps, each addressing specific aspects of image quality.

2.3Retinex-based: Retinex-based image enhancement is a class of image processing techniques that aims to improve the visual quality and perceived brightness and color balance of an image by removing variations in illumination and reflectance. The Retinex algorithm is based on the human visual system's ability to perceive objects' colors consistently under varying lighting conditions. It was first introduced by Land and McCann in 1971.The primary goal of Retinex-based image enhancement is to separate the illumination component (often called the "lightness" or "luminance") from the reflectance component (color and texture) in an image, allowing for more accurate and consistent representation of colors and details. This can be particularly beneficial in various applications, including photography, computer vision, and image analysis.

2.4Red Channel: Enhancing the red channel of an image specifically refers to improving the quality and appearance of the red color information in an image. In digital images, including those captured by cameras or generated digitally, color information is often represented as a combination of red (R), green (G), and blue (B) channels. Enhancing the red channel involves adjusting the pixel values in the red channel to achieve certain desired effects or improvements in the image. This can be done using various image processing techniques**.**

2.5Regression-based: Regression-based image enhancement is an approach that uses regression models, often machine learning or deep learning algorithms, to improve the quality and visual characteristics of an image. In this context, "regression" typically refers to a statistical technique where the goal is to predict a continuous target variable based on input features. In the context of image enhancement, regression-based methods leverage the relationship between input image data and the desired output (enhanced) image. The input features can include pixel values, local image patches, or other image-related information, and the regression model is trained to learn how to transform the input image to a more visually pleasing or improved version.

2.6MSE (Mean Squared Error): MSE, which stands for Mean Squared Error, is a common metric used in image processing and various other fields to measure the average squared difference between the values (e.g., pixel values) in two images or data sets. It quantifies the average of the squared differences between the original or reference data and the data you want to compare or evaluate.In the context of image processing, MSE is often used to assess the quality of an image enhancement or image reconstruction process**.**

2.7PSNR (Peak Signal-to-Noise Ratio): PSNR, or Peak Signal-to-Noise Ratio, is a widely used quality metric in image and video processing. It quantifies the quality of a processed or compressed image by measuring the ratio of the maximum possible power of a signal (the original, unaltered image) to the power of the noise (errors or discrepancies) that the processed image contains. A higher PSNR value indicates a better quality image, as it represents a stronger signal compared to the noise. PSNR is expressed in decibels (dB) and provides a quantitative measure of image quality. A higher PSNR value indicates less distortion and, therefore, better image quality. The peak value, R, is used to normalize the error in terms of the maximum possible pixel value, making the metric scale-independent and allowing for comparisons between images with different bit depths or dynamic ranges.

2.8The Structural Similarity Index (SSIM): SSIM quantifies how similar two images are in terms of structural information, textures, and patterns as perceived by the human visual system. It is designed to go beyond simple pixel-wise comparisons, considering luminance, contrast, and structure to provide a more comprehensive measure of image quality.

2.9UCIQE (Universal Image Quality Index): The Universal Image Quality Index (UCIQE) is a metric used for assessing the quality of images, particularly in the field of image processing and computer vision. UCIQE provides a single numerical value that quantifies the perceived quality of an image by taking into account various factors affecting human visual perception. UCIQE combines multiple image quality attributes and is designed to be a comprehensive metric that goes beyond simple pixel-wise comparisons.

Method: COPRAS (Complex Proportionality Assessment) is one of the most used (MCTM) methods, and the ratio of the best solution Determining the solution with the best rate in the set of possible alternatives by Provides a better alternative Bad Solution. This technique has Decision making problems Various to solve used by researchers [16]. The COPRAS-G method requires identifying selection criteria; evaluating information related to these criteria, and developing methods to evaluate Meeting the participant's needs Criteria for doing in order to assess the overall performance of the surrogate. Decision analysis involves a Decision Maker (DM) Situation to do consider a particular set of alternatives and select one among several alternatives, usually with conflicting criteria. For this reason, the developed complexity proportionality assessment (COPRAS) method can be used [17]. In 1996 in Lithuania COPRAS (Complex Proportion evaluation) method was developed. Construction economics, real estate and management. One of the articles assesses the risks involved in construction projects. The assessment is based on various multi-objective assessment methods. The risk assessment indices are selected considering the interests, objectives and factors of the countries that influence the construction efficiency and real estate price increase [18] to describe and consider the task model. Complex Proportionality Assessment (COPRAS) Method Similar to any many other criteria will make the decision (MCDM) tool, first Proposed COBRAS method of several related criteria basically for alternatives Used to prioritize criterion weights. This method is better and Worst-Best Solutions Best decision considering Selecting alternatives [19]. Cobras approach is used for device tool choice; Because of this the triangle Ambiguous numbers are selected their computational performance. Three area specialists are selected to assign weights and by way of combining the fuzzy cobra's method, System 1 (MC1) and device 2(MC2) similarly are ranked, with way of ma chine three and four. -based totally approach is utilized in mixture with fuzzy. COPRAS assess the complexity of consumer dating management (CRM) performance. A combined choice matrix is obtained from a panel of 20 specialists offered 3 options with set, and 5 criteria Assessment are done [20].COPRAS to resolve MCDM issues, wherein the weights of the criteria and Performance ratings of alternatives are absolute Based on linguistic terms are calculated. Comparison of criteria Importance calculated and Cobras method become used to assess renovation strategies [21].This have a look at ambitions to develop the impact of latest overall performance metrics in TPM and COPRAS in an ambiguous context Primarily multi-criteria selection based on opinions Use the do method. Looseness of paper is prepared as follows. Section 1 provides an overview of the disruption and a literature review. Section 2 focuses on the Cobras-G approach and the corresponding literature review. Sections three and four introduce the core principles of the Cobras-G methodology, emphasizing its utilization based on the recommended approach, which is described as COPRAS-G. This complex proportional estimation approach employs numerical data represented using the Grey Systems Theory framework. The Cobras-G concept approach is rooted in Grey Systems Theory programs, real-world decision-making scenarios, and duration-based standard values. Diploma [23].COPRAS method changed into the most relevant social media platform Rank and choose is used. Proposed Applicability of the structure We proved and proved the character [24].COPRAS (Complex Proportionality Assessment) To examine Cumulative of an alternative Performance, it is essential become aware of the maximum vital criteria, examine the options and compare the facts Depending on those criteria to fulfill the wishes of the DMs to compare grades evaluation involves a situation in which a DM must pick amongst several downloaded alternatives given a selected set of commonly conflicting standards. For this motive, the developed complex proportionality evaluation (COPRAS) method can be used in real situations, alternatives The criteria for assessment are vague is related to the factor, And the values of the standards are real Cannot be expressed with numbers [25].

3. RESULTS AND DISCUSSION

TABLE 1. Image enhancement

Method	MSE	PSNR	SSIM	UCIQE
fusion-based	0.8679	18.75	0.8162	0.6414
two-step-based	1.1146	17.66	0.7199	0.5776
retinex-based	1.3531	16.88	0.6233	0.6062
Red channel	5.13	11.03	0.4999	0.5852
regression-based	1.1365	17.58	0.6543	0.5971

Table 1 shows comparison of above table MSE (Mean Squared Error): Lower values are better. The "Fusion-Based" method has the lowest MSE, indicating it produces results closest to the original image. PSNR (Peak Signal-to-Noise Ratio): Higher values are better. Again, the "Fusion-Based" method has the highest PSNR, indicating higher fidelity in the enhanced images. SSIM (Structural Similarity Index): Higher values are better. The "Fusion-Based" method also has the highest SSIM, suggesting that it retains more structural information compared to the other methods. UCIQE (Universal Image Quality Index): The "Fusion-Based" method has the highest UCIQE, which implies that it provides the best overall image quality based on this metric.

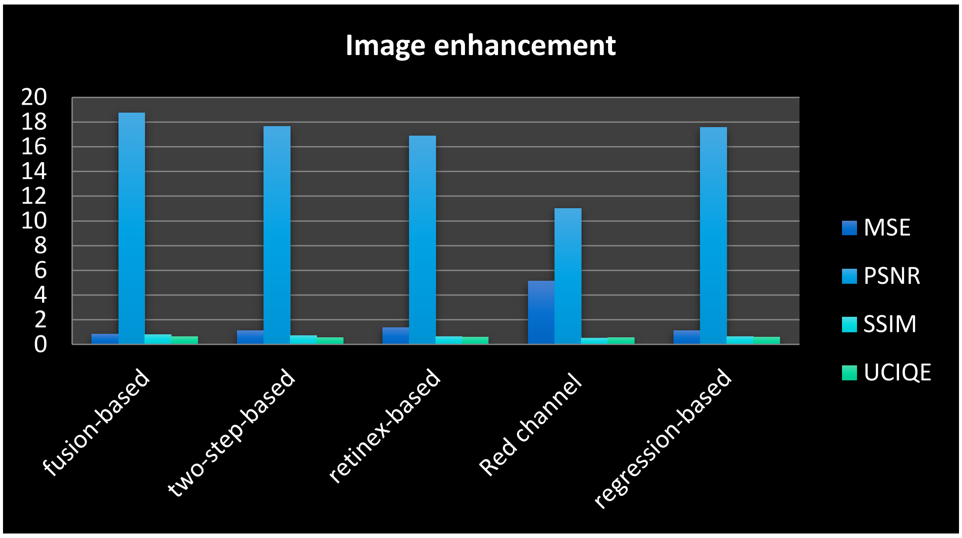

FIGURE 1. image enhancement

Figure 1 illustrate the graphical representation of image enhancement

TABLE 2. Normalized Data

MSE	PSNR	SSIM	UCIQE
0.0904	0.2289	0.2463	0.2133
0.1161	0.2157	0.2173	0.1921
0.1409	0.2061	0.1881	0.2016
0.5343	0.1347	0.1509	0.1946
0.1184	0.2146	0.1975	0.1985

Table 2 shows explain of normalized data MSE (Mean Squared Error): This is a metric that quantifies the average squared difference between the pixel values of the original reference image and the processed or distorted image. In this table, the MSE values are relatively small, ranging from 0.0904 to 0.5343. Lower MSE values indicate less distortion or error in the processed images. PSNR (Peak Signal-to-Noise Ratio): PSNR is a metric that measures the quality of an image by comparing it to the reference image. The PSNR values are in the range of 0.1347 to 0.2289, with higher values indicating better image quality. PSNR is expressed in decibels (dB).SSIM (Structural Similarity Index): SSIM is a metric that assesses the structural similarity between two images. The SSIM values range from 0.1509 to 0.2463. Higher SSIM values indicate a closer match in terms of structure, contrast, and texture between the processed and reference images. UCIQE (Universal Image Quality Index): UCIQE is a comprehensive image quality metric that takes into account various factors affecting human visual perception. The UCIQE values in the table vary from 0.1921 to 0.2133, with higher values suggesting better image quality.

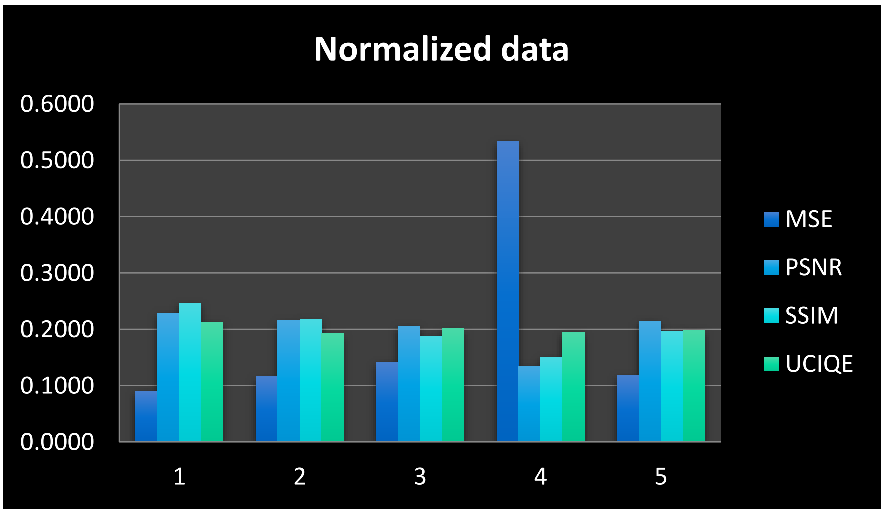

FIGURE 2. Normalized Data

Figure 2 illustrate the graphical representation of Normalized Data

TABLE 3. Weight ages

Weight			
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25

Table 3 shows weight ages the interpretation of these weights suggests that all four metrics (MSE, PSNR, SSIM, and UCIQE) are considered equally important in the assessment of image quality.

TABLE 4. Weighted normalized decision matrix

Weighted normalized decision matrix			
0.02	0.06	0.06	0.05
0.03	0.05	0.05	0.05
0.04	0.05	0.05	0.05
0.13	0.03	0.04	0.05
0.03	0.05	0.05	0.05

Table 4 shows weighted normalized decision matrix. The weights and normalized scores in the matrix are used to calculate a weighted sum or weighted average for each alternative. This allows decision-makers to compare and rank the alternatives based on their overall performance, considering the relative importance of the criteria. To calculate the overall performance score for the first alternative, you would multiply each criterion's score by its respective weight, and then sum the products: Overall Performance (Alternative1)=(0.02* Weight1)+(0.06* Weight2)+(0.06* Weight3)+(0.05* Weight4).

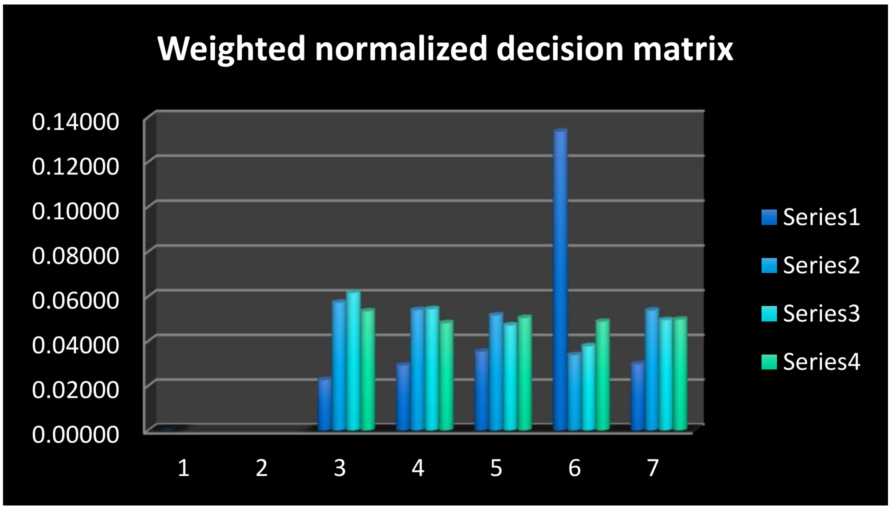

FIGURE 3. weighted normalized decision matrix

Figure 3 illustrate the graphical representation of weighted normalized decision matrix

TABLE 5. image enhancement Bi, Ci, Min (Ci)/Ci

Bi	Ci	Min(Ci)/Ci
0.080	0.115	0.7516
0.087	0.097	0.8865
0.167	0.086	1.0000
0.083	0.099	0.8723

Table 5 shows Bi,Ci, Min(ci\ci) , The Bi value is 0.080, the Ci value is 0.115, and Min(Ci)/Ci is approximately 0.7516. This means that the technique with Bi = 0.080 has a Ci value that is about 75.16% as good as the best-performing technique, which has the minimum Ci value. The Bi value is 0.083, the Ci value is 0.102, and Min(Ci)/Ci is approximately 0.8440. The technique with Bi = 0.083 is about 84.40% as good as the best technique. This pattern continues for the other rows, where the Min(Ci)/Ci values represent the relative performance of each technique compared to the best-performing one

TABLE 6. Final Result of image enhancement

Method	Qi	Ui	Rank
fusion-based	0.166	58.9003	5
two-step-based	0.180	63.7599	4
retinex-based	0.189	66.8449	2
Red channel	0.282	100.0000	1
regression-based	0.183	65.0257	3

Table 6 show compare the qi and ui value ,Red Channel: The "Red Channel" method has the highest Qi and Ui values. This indicates that, based on these metrics, the "Red Channel" method performs the best among the five methods and provides the highest image quality or enhancement. Retinex-Based: The "Retinex-Based" method has the second-highest Qi and Ui values, suggesting it is the second-best performing method among the options. Two-Step-Based: The "Two-Step-Based" method comes next in terms of both Qi and Ui values. Regression-Based: The "Regression-Based" method has slightly lower Qi and Ui values compared to the "Two-Step-Based" method. Fusion-Based: The "Fusion-Based" method has the lowest Qi and Ui values among the methods, indicating that it is the least performing method based on these metrics.

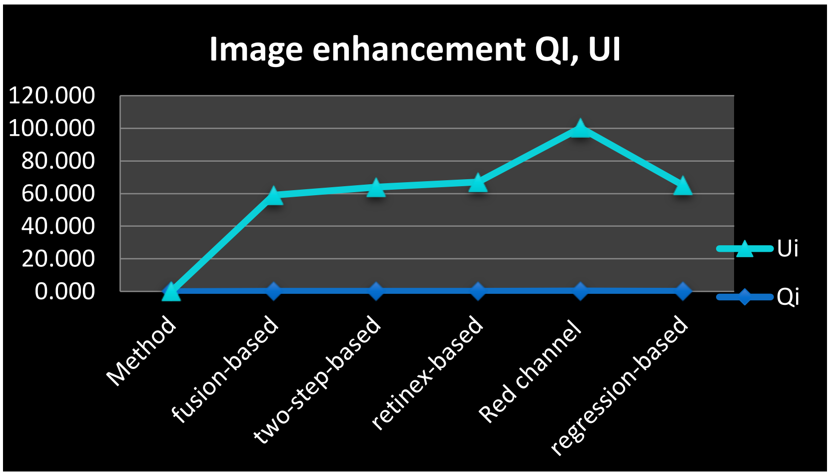

FIGURE 4. image enhancement Qi, Ui

Figure 4 illustrate the graphical representation of Qi, Ui value.

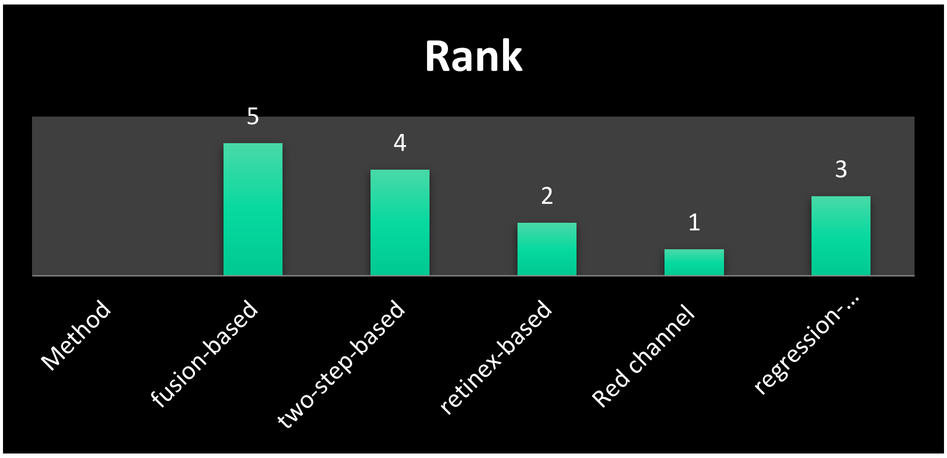

FIGURE 5. Rank

Figure 5 Shows ranking of image enhancement, Red channel is got the first rank whereas is the fusion based is having the lowest rank.

4. CONCLUSION

Image enhancement serves as a cornerstone in the field of image processing, with the primary objective of refining the visual quality and interpretability of images across diverse applications. Through the exploration of various enhancement methods, including fusion-based, two-step-based, retinex-based, red channel enhancement, and regression-based techniques, it becomes evident that a multitude of tools are available to cater to different image improvement needs. Each method offers its unique advantages and may be suited to particular scenarios. Fusion-based methods, for instance, excel in blending multiple images to create a more informative composite. Two-step-based techniques provide a structured approach to enhance images, while retinex-based methods aim at ensuring consistent illumination and reflectance in the final images. Red channel enhancement prioritizes the intensification of red color information, and regression-based approaches leverage machine learning to provide flexible and data-driven enhancement. The choice of an appropriate image enhancement technique depends on the specific requirements of the task at hand. It is crucial to consider factors such as the nature of the input images, computational efficiency, and the critical attributes to be improved, whether it be sharpness, color balance, or noise reduction. It is essential to strike a balance between these factors to ensure that the selected method aligns with the desired outcomes. While MSE and PSNR offer pixel-level comparisons and signal-to-noise ratios, SSIM provides a more perceptually meaningful assessment, and UCIQE factors in human visual perception. Image enhancement plays an indispensable role in a multitude of domains, from medical imaging and satellite remote sensing to photography and surveillance. Its utility extends beyond mere visual aesthetics, contributing significantly to the effectiveness and reliability of image-based applications. By systematically evaluating the various enhancement methods and considering the specific requirements, it is possible to harness the full potential of image enhancement to meet the diverse needs of a wide array of industries and disciplines.

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