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Contrast-Guided Adaptive Multiscale Retinex for Enhanced Satellite Image Visualization

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Abstract- Satellite images generally have low contrast, non- uniform illumination, and structural details visibility suffer from atmospheric interference, sensor limitations, and different acquisition conditions, which greatly hamper visual analysis and interpretation. In this paper, a Contrast-Guided Adaptive Multiscale Retinex (CG-AMSR) approach is proposed for satellite image visualization enhancement. Based on the theory of Multiscale Retinex with New Kernel (MSRNK), the authors of the method adaptive contrast guidance to control enhancement strength locally while retaining natural appearance. Multiscale processing is used for balancing global illumination correction and local detail enhancement, and an improved kernel formulation is implemented to stabilize illumination normalization without generating halo artifacts or saturation effects. Moreover, contrast-aware weighting and normalization techniques are used to preserve structural integrity and maintain the overall tonal balance. The authors assess the proposed model's effectiveness through visual examination and by using objective quality indices, such as entropy, PSNR, SSIM, and contrast enhancement index. The proposed approach outperforms the other three baseline methods quantitatively and qualitatively in terms of contrast enhancement as well as detail preservation. Also, the resultant images from the proposed method show more visual clarity and popularity. As such, the method can be considered as a viable candidate for handling real-world satellite image analysis and visualization problems.

Index Terms- Satellite Image Enhancement, Multiscale Retinex, Contrast-Guided Enhancement, Illumination Normalization, ImageVisualization,MSRNK, Adaptive Contrast Enhancement

I. INTRODUCTION

Digital image processing (DIP) is a technique of converting raw image data into a form that is more understandable to human perception and easily analyzable by machines. It is a very important tool of collecting, improving, analyzing, and interpreting visual information. Due to the rapid development of imaging sensors and processing resources, DIP methods have been indispensable in several fields of application such as medical imaging, surveillance, remote sensing, and satellite image analysis. Image enhancement is one of the critical preprocessing steps among various image processing operations that is intended to improve the visual quality and allow the extraction of valuable information from low-quality or degraded images. Due to complex imaging settings, satellite and geophysical images in particular frequently suffer from low contrast, uneven illumination, air scattering, sensor noise, and limited dynamic range. The visibility of significant surface elements like flora, water bodies, landforms, and urban structures is greatly impacted by these difficulties. For applications such as environmental monitoring, geographic information systems (GIS), urban planning, disaster management, and decision-making based on remote sensing, satellite images must be effectively enhanced. One way of improving the distinction between objects and their background is contrast enhancement, which is by far the most widely used picture enhancement technique, achieved by scattering the intensity values. Sometimes, traditional contrast enhancement techniques such as Histogram Equalization (HE) and Contrast Limited Adaptive Histogram Equalization (CLAHE) can be quite effective and are computationally very simple. However, when they are applied to complex satellite images especially with uneven illumination, these techniques often suffer from drawbacks such as saturation, noise amplification, over- enhancement, and loss of natural appearance. In an attempt to overcome such limitations, model-based

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enhancement methods among which Retinex-based image enhancement techniques are especially popular have attracted a lot of attention. The Retinex theory models an image as a combination of illumination and reflectance components and is based on the human visual perception. Retinex methods operate on the principle of reflectance component enhancement by first estimating and then suppressing the illumination component. As a result, structural features are retained and contrast as well as visibility gets enhanced. Research has indicated that the Single Scale Retinex (SSR) and Multiscale Retinex (MSR) methods were able to achieve a good compromise between overall lighting adjustment and local texture enhancement. Multiscale Retinex algorithms, by combining different spatial scales, allow the simultaneous retention of both fine details and the overall image layout, thus significantly boosting enhancement results. In contrast, traditional MSR methods rely on Gaussian surround functions, which may cause instability, edge distortion, and halo artifacts in various lighting situations. To overcome these limitations, Multiscale Retinex with New Kernel (MSRNK), which features a sophisticated kernel structure that ensures integrability, scale invariance, and efficient illumination normalization, was proposed. MSRNK, in comparison to standard Retinex methods, has been able to successfully enhance contrast and reduce unwanted artifacts. However, fixed-parameter Retinex methods are still not good at dealing with the wide range of contrast distributions in satellite images, even after these enhancements. In order to avoid over-enhancing or missing features, different parts of the same image may have to be given different amounts of augmentation. This limitation points to the need for adaptive enhancement methods that can smartly guide the Retinex operation based on local image properties, in particular, changes in contrast. Therefore, the present study proposes a Contrast-Guided Adaptive Multiscale Retinex architecture for better viewing of satellite images. The proposed method regulates the enhancement strength locally and independently by fusing the multiscale Retinex processing with the adaptive contrast guidance.

The proposed approach can achieve efficient illumination correction, higher contrast, and maintaining the natural appearance by integrating contrast-aware weighting, normalizing methods, and the elevated kernel formation.

Through qualitative and quantitative comparisons with conventional enhancement methods, the appropriateness of the proposed method for satellite and geophysical image processing is demonstrated.

II. LITERATURE REVIEW

As part of digital image processing, there has been a lot of work done on image enhancement, with a special focus on improving the visibility and understandability of pictures taken under challenging conditions such as low light, haze, noise, and uneven light. Retinax-based methods, which take a cue from human visual perception, have been found to be effective ways of solving the problems of illumination normalization and contrast enhancement in a range of imaging fields, for example, infrared, satellite, underwater, and environmental monitoring applications.

Yuan et al. [1] proposed an infrared image enhancement method that integrates Multiscale Retinex with a sequential guided image filter to increase detail preservation and reduce noise. Their method achieved an increase of both edge sharpness and local contrast in infrared imaging. However, the guided filtering step hikes the processing cost and may limit the real-time practicality of the method for large satellite data sets. With a focus on smart environmental monitoring, Baazeem [2] has also developed an adaptive statistical quality evaluation system for real-time updating of optical and infrared remote sensing images. Although the method is adaptive, it heavily relies on statistical modeling that may not be effective in very uneven lighting scenarios.

Improving the quality of complex scenes such as underwater and nature has been the focus of the recent studies and methods. In their deep dive into human perception of the underwater environment, Zhu et al. [3] pointed out the role of enhancement solutions, e.g., fusion-based and Retinex-based, in dealing with light scattering and absorption. To facilitate further analysis, Porto Marques [4] gave the example of contrast enhancement as one of the preprocessing steps in his discourse on the computer vision tools for environmental surveillance. The above articles underline the importance of the powerful and versatile creation of artificial samples, however, they don't concentrate on the unique challenges of satellite images.

Retinex-based enhancement for satellite image and remote sensing is reviewed in many papers. To enhance visibility under such conditions, Pazhani and Periyanayagi [5] presented MSR- based dehazing framework for remote sensing images based on Retinex a HDRI processing model. Nevertheless, their approach may introduce artifacts in non-hazy images, and they concentrate primarily on the degradation of haze. By integrating deep learning and Retinex theory, an improved Retinex-Net for multispectral satellite image enhancement is proposed in [6] by Liu et al. Deep learning approaches are much more like practical, but in resource-poor environments, their application is difficult due to high computational complexity and need for large annotated data sets.

Retinex models have been based on hybrid and learning frameworks in recent deep learning developments. By means of data-driven optimization, Wang et al. [7] obtained superior results in a low-light image enhancement application by proposing a multi-scale Retinex unfolding network. For mine monitoring, Tian et al. [8] proposed also an improved Retinex- based enhancement method. They all rely on training data and models, although they work well. Nevertheless, due to the complexity of the models it is less feasible to apply them to generic satellite image enhancement without substantial retraining. Adaptive Retinex algorithms have also been used in the restoration of grayscale and underwater images. For underwater images, Zhou et al. [9] they proposed a multi-scale Retinex based adaptive grayscale transform to improve the contrast and preserve structural details. Tejas et al. [10] and Rajalakhmi et al. [11] combined the Multiscale Retinex withHistogram Equalization to enhance the image recognition accuracy. Although such combination methods enhance contrast, substantial histogram manipulation usually makes the image over-enhanced and unnatural in appearance.

Li and Ou [12] verified the monitoring activity of visual quality was improved in application of the multiscale Retinex algorithm to the remote sensing images for ecological environment analysis under ecological and environmental monitoring. Based on multi- image fusion, Han et al. [13] addressed the challenge of low-light enhancement for deep-space images focusing on ultralow illumination conditions. For the case of remotely sensed images, Singh et al. [14] introduced a texture-dependent enhancement scheme based on fractional-order multiscale Retinex, which achieved a better texture preservation, but required higher computational cost.

Sophisticated enhancement frameworks based on fusion methodologies and generative models have also been explored in the recent literature. Mini and Amudha Bhomini [15], in their comprehensive review on satellite image enhancement techniques, enumerated the pros and cons of traditional and modern approaches. For satellite image dehazing, Zhang et al.[16] proposed MCA-GAN, which needs a large amount of training data and obtains good result based on multi-scale contextual attention. Li and Zhou [17] further affirmed the effectiveness of multiscale and illumination-aware methods with a multi-scale fusion framework integrating Retinex and transmittance optimization for underwater image restoration.

The ever-growing body of published literature indicates that while Multiscale Retinex and its variants are effective for illumination normalization and contrast enhancement, a number of them have fixed parameter settings, nonlinear computational complexity, generation of artifacts, or dependence on large training datasets. As a consequence of these drawbacks, a Contrast-Guided Adaptive Multiscale Retinex (CGAMSR) approach is proposed, which adaptively adjusts the degree of enhancement based on the local contrast information, ensuring better visual quality, robustness and detail preservation for satellite image visualization with minimal computational burden.

III. METHODOLOGY

In this section, the formation of the proposed CG-AMSR scheme for satellite image enhancement is

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presented. The method seeks to preserve the structural components and natural look of the image while improving contrast and visibility under uneven illumination. The proposed approach employs a modular image processing pipeline which can be extended and linked with high performance optimization methodologies.

System Architecture

Processing and analysis modules constitute two the principal components in the overall architecture for the image.

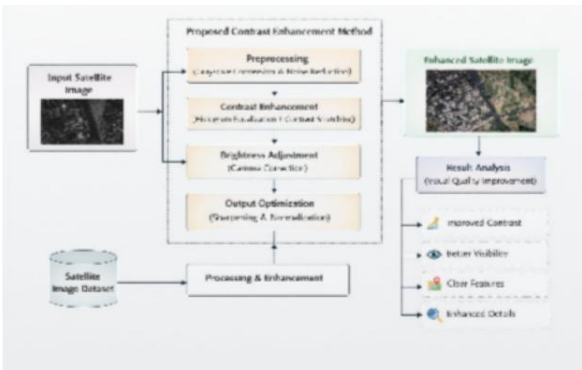

Fig: Block diagram of the proposed satellite image contrast enhancement system.

Building Blocks of Image Processing

a) Satellite Image Input: The system accepts color or grayscale satellite images affected by atmospheric degradation,obfuscation,or non-uniform illumination.
b) To compensate for intensity variations, the preprocessing module handles image normalization, conversion of color spaces, and logarithm-based transformation.
c) To consider both local information and global illumination, the Multiscale Retinex Processing Module performs Retinex enhancement on different spatial scales.
d) Better lighting Estimation Kernel: utilizes scale invariant, integrable kernel unit that borrows some ideas in MSRNK for better lighting estimation.
e) Contrast-Guided Adaptive Fusion Module employs contrast based adaptive weights to fuse multiscale outputs at the dynamic state.
f) After-processing and reconstruction After-processing and reconstruction The final enhanced image is generated by reassembling and normalizing the luminance and chrominance signals.

Evaluation Components

1. The objective quality evaluation is performed by computing the quantitative measures of entropy, PSNR, SSIM and the contrast enhancement index.
2. The CA module compares enhanced results with standard contrast enhancement methods.

Preprocessing Stage

To ensure consistent and dependable enhancement, the provided satellite image is preprocessed. For color images, a transformation to a luminance–chrominance color model is applied which separates the luminance component from the chrominance components. The luminance channel is also processed by Retinex to avoid color distortion. To reduce the

The multiscale Retinex algorithm is applied to accommodate varying illumination at different spatial scales. The selection of multiple scales with various kernel sizes allows to capture fine local details and larger-scale illumination structures. The Retinex output at each scale is calculated as the logarithmic difference of the original luminance image and the estimated illumination component. This approach ensures uniform enhancement by combining global brightness compensation with local contrast enhancement amplification.

improved Illumination Estimation Using New Kernel

The generally employed Gaussian kernels in the conventional Multiscale Retinex algorithms may cause some distortion of edges and halo effects around edges. To overcome these limitations, a novel illumination estimation kernel derived from the Multiscale Retinex with the New Kernel (MSRNK) approach is proposed. The kernel enables accurate illumination estimation at multiple scales due to its integrability and scale-invariance properties. In heterogeneous areas of satellite images, this formulation also reduces artifacts and preserves edge consistency while enhancing contrast.

Contrast-Guided Adaptive Fusion

To dynamically control the enhancement strength at different positions of the image, a contrast-guided adaptive weighting strategy is developed. To specify the regions more strongly to be augmented, local contrast values are calculated. To prevent over-enhancement and saturation, the bright areas are treated with conservative weights, while high-contrast areas obtain larger weights. These weights adaptively are used to integrate the multiscale retinex outputs and an enhanced luminance image generation with separated regions is obtained.

Post-Processing and Image Reconstruction

In order to map the intensity of pixels to a displayable range and keep tonal balance, the fused luminance image is normalised. The enhanced image for color satellite image is obtained by recombining the enhanced luminance with the original chrominance components. This stage ensures the natural color appearance and structural coherence of the output image.

Evaluation and Performance Analysis

The efficiency of the proposed CG-AMSR scheme is evaluated through qualitative and quantitative evaluations. To assess contrast enhancement, visibility of detail and suppression of artifacts, a visual evaluation is performed. For quantitative evaluation, the quality of the image is assessed by objective measures such as entropy, peak signal to noise ratio (PSNR), structural similarity index (SSIM) and contrast enhancement index. To demonstrate the superiority of the proposed method, the results are compared with those of traditional enhancement methods, such as Histogram Equalization (HE), Contrast Limited Adaptive Histogram Equalization (CLAHE), and conventional Multiscale Retinex.

Scope for Future Enhancement

Although the contrast-guided Retinex based enhancement is the primary focus of the proposed system, the design allows for additional enhancement. Potential improvements include automatic parameter tuning, incorporation of learning-based contrast estimation, and extension to multispectral and hyperspectral satellite images. In projects with large scale remote sensing and geophysical inversion, these extensions can further improve robustness and applicability.

A) Novelty of the Project

This contribution is novel and unique, as it addresses the issues of poor contrast and nonuniform illumination in remote sensing images through fusion of adaptived contrast guidence and multi- scale Retinex-based enhancement scheme. Unlike traditional enhancement methods that perform the same processing all over the image, the proposed approach introduces adaptivity and illumination-aware processing to improve the visualization quality.The main contributions of this project are as follows:

1. Adaptive Contrast-Guided Enhancement Framework:
   a. Traditional contrast enhancement and Retinex-based methods are generally pre-defined or fixed parameter in nature, which do not take into account the regional variation of contrast in satellite imagery.
   b. The proposed framework introduces a contrast-driven adaptive process that adapt enhancement strength on the basis of local contrast attributes.
   c. This adaptive manner of behavior allows for a meaningful enhancement of low contrast regions, since it compensates for low contrast while restraining over-enhancement in the bright regions.
   d. Therefore, the proposed approach preserves meaningful structural regional details and leads to uniform contrast enhancement over different regions of the satellite image.

2. Improved Illumination Estimation Using Multiscale Retinex with New Kernel:
   a. Gaussian kernels are the basis of classical Multiscale Retinex methods, leading c b instability and halo effects near crisp edges.
   b. Inspired by the MSRNK scheme, an improved, integrable and scale invariant kernel for illumination estimation is introduced within the proposed framework.
   c. This kernel design guarantees that lighting is normalized stably over multiple spatial scales.
   d. In enhanced satellite images, the proposed kernel substantially suppresses artifacts, maintaining

edge consistence and natural brightness.

3. Region-Adaptive Multiscale Fusion Strategy:
  a. Existing multiscale enhancement methods often aggregate outputs with heuristic or fixed weights.
  b. In the proposed method, a local contrast-based region-adaptive fusion scheme is applied.
  c. To fuse multiscale Retinex outputs, spatial contrast aware adaptive weights are used.
  d. Such strategy makes it possible to keep both fine local details and global illumination features simultaneously.

4. Preservation of Natural Appearance and Structural Integrity:
  a. Saturation, color distortion, or unnaturalness appear to many traditional enhancement methods.
  b. The proposed framework preserves the natural color appearance through contrast-aware normalization and Retinex processing on luminance.
  c. Structural elements, such as edges, textures, and object boundaries are preserved without amplifying noise.
  d. This results in satellite images that are visually uniform and intelligible, and thus they are suitable for further analysis.

5. Computational Efficiency and Model Independence:
  a. An increasing number of recent super-resolution methods rely on deep learning models, which require large training datasets and high-performance computers.
  b. The proposed method works in the absence of complex learning models or training data.
  c. This model-free strategy leads to an easier deployment and less computational burden in many satellite imaging scenarios.
  d. Therefore, the system can be applied to the real-life problems with scarce labeled data or computing power.

6. Applicability to Diverse Satellite and Geophysical Imaging Conditions:
  a. Satellite images have divergent lighting, weather and terrain conditions.
  b. The proposed framework, due to its adaptive and multiscale nature, can be expected to perform reliably under different imaging conditions.
  c. The method may be applied for a spate of satellite and geo- physi image visualization applications including land use analysis, environmental monitoring, and interpretation of remote sensing.

Our method provides a novel, cost- effective and practical solution for satellite image enhancement, which overcomes the limitations of existing contrast enhancement and retinex-based methods by jointly considering adaptive contrast guidance, improved multiscale illumination estimation and region-aware fusion.

B) Dataset Analysis and Description

Since the goal of the proposed work is image quality enhancement rather than training a model for semantic segmentation or classification, it does not use a structured or annotated dataset. The properties of the dataset are as follows:

Use of Dataset: This work does not rely on a pre-defined dataset. Instead train sets and test sets are generated implicitly during the work. The proposed method considers each input image as a separate entity.

Images collection: For the purpose of experimental verification, a maximum of ten satellite images were collected manually from publicly available sources.

Nature of Photographs: The chosen images depict different environmental conditions namely urban, vegetated and water areas as well as areas with mixed terrain.

Image features: The observed images have typical features of remote sensing problems such as:

a) Non-uniform illumination
b) Low contrast
c) Atmospheric haze
d) Reduced structural visibility

Processing Method: In the proposed MSRNK framework, each image is separately processed by the Adaptive Contrast-Guided Multiscale Retinex with Novel Kernel. No training, no feature learning, no dataset-based optimization is performed.

Evaluation Technique: Normal statistical analysis of datasets is meaningless since no labeled information is used. The performance evaluation is realized by visually qualitative comparison and quantitative image quality indices.

Limitations of Scope: Only a few representative satellite pictures are used in the experiment. But this is enough to show the effectiveness of the proposed method of enhancement.

The summary is simple and to the point, exactly what a summary should be. Moreover, to facilitate recollection of the original text, these points maintain the same sequence of presentation as in it. The suggestions are based only on typical, most worthy of attention points.

Important Things to keep in mind:

1. Small Sample Size: The entire validation was based a on a handful of hand collected images.
2. Lack of ground truth reference: A perfect ground-truth enhanced image doesn't exist because enhancement is a matter of opinion.
3. Missing aspect of evaluation: PSNR and SSIM, albeit being structural similarity indices, cannot truly convey the perceptual quality.
4. Scope of Generalisation: To demonstrate the validity of the proposed method, some typical satellite images are used. Here contribution on very noisy or hyperspectral images is one of the aspects planned to be explored further.
5. Parameter Sensitivity: Multiscale parameters and Kernal design determine how strong the enhancement will be and thus they must be changed very carefully.

C.*)* Algorithm Justifications:

The purpose of this work is to enhance the view of the satellite images by using a Contrast-Guided Adaptive Multiscale Retinex algorithm. The selected algorithmic framework is justified by the inherent disadvantages of conventional rule-based or global contrast enhancement approaches, which are often used in digital image processing.

Challenges of Rule-Based Enhancement Methods
Traditional image enhancement techniques for satellite images such as linear contrast stretching and histogram equalization are based on global intensity transformation and fixed rules. These techniques are often unable to cope with spatially varying contrast and illumination in satellite images. As a consequence, these methods may lead to noise amplification, loss of meaningful geophysical information, over-enhancement in bright regions and under-enhancement in dark regions.

Benefits of Retinex-Based Enhancement
Retinex-based methods address these limitations by modeling an image as the product of illumination and reflectance. The Multiscale Retinex algorithm, by processing in multiple spatial scales, enhances local and global image representation. As a result, it is effective for satellite images where dynamic range changes and complex illumination patterns are very common.

- Contrast-Guided Adaptive Strategy

A contrast-guided adaptation process is integrated into the proposed method to further improve the enhancement result. The enhancement strength is adaptively controlled in different regions of the image, based on the local contrast. The low- contrast regions are enhanced more strongly whilst the high-contrast regions are preserved from over-saturation and over- deformation of structure.

Algorithm Selection Rationale
Contrast-Guided Adaptive Multiscale Retinex is recommended for its invariance to illumination changes, data independence and its ability enhance contrast without the need of a significant amount of parameter tuning. Its multiscale and adaptive nature makes it more suitable for satellite image enhancement than visual coherence and computational efficiency are preserved.

IV. ARCHITECHTURE IMPLEMENTATION

Based on multiscale Retinex theory, an adaptive contrast enhancement framework for the visualization of satellite images is presented. The architecture consists of a well supervised image processing pipeline, which handles the acquisition of input images, the processing for enhancement, and the generation of output images. The following section describes the complete data flow, starting from the input image and ending with the enhanced output.

1. Acquisition of Input:

Input: The method takes as input a low contrast s a t e l l i t e image acquired from satellite sensors or remote sensing data products.
These images have one or more of the following defects: uneven lighting. Low contrast. Atmospheric deterioration.

2. Stage of Preprocessing:

Raw satellite image as input Processing: Processing of pixel intensities to a given range Converting RGB to grayscale or luminance is a choice feature.
Output: A processed image for multiscale and logarithmic operations

3. Multiscale Illumination Estimation

Input: Preprocessed image

Processing:
- Multiple Gaussiansurround functions are employed with different standard deviations.
- Illumination components are estimated at multiple spatial scales

Output: A set of multiscale illumination maps represent both local and global illumination characteristics.

4. Retinex-Based Enhancement

Input:
- image that has been preprocessed
- Maps of multiscale illumination

Processing:
- Logarithmic differencing operations are performed between each illumination map and the input image.
- Images of enhanced reflectance are generated at each scale.
- Output: Multiscale Retinex processed photos

5. Adaptive Multiscale Fusion

Input: Retinex computations at various scales
Processing:
- The results of enhancement from all scales are integrated by a weighted fusion scheme.
- Local detail preservation and global brightness enhancement are well balanced.

Output: Image:Reflectance enhancement based on fusion.

6. Contrast-Guided Adaptation

Input: Improved picture fused.

Processing:
- Local contrast metrics are computed for each subregion of the image.
- The contrast distribution is used in the adaptive gain control application.
- The underemphasized low-contrast regions are enhanced without overemphasizing high- contrast regions.

Output: contrast-modified improved image

7. Detail Preservation and Noise Suppression

Input: image with contrast correction
Processing:

- Methods for edge-preserving filtering, such as guided filtering, are applied.
- enhancement-induced noise magnification is reduced

Output: image with reduced noise and maintained details

8. Dynamic Range Adjustment

Input: improved and refined image
Processing:

- The pixel intensity values are scaled and

compressed.
- Clipping and saturation artifacts are suppressed.

Output: Enhanced image is ready for display.

9. Output Generation

Final Output:

The system produces a satellite image with enhanced:

- Higher contrast lighting
- The details of the structure were preserved.
- It's natural-looking appearance

These enhanced images may serve as inputs to subsequent processing of satellite images for applications such as object detection, land use classification, and environment surveillance.

Overall Data Flow

1. Input to the system is a satellite image.
2. The image is normalized and processed in advance.
3. Multiscale illumination maps are generated.
4. There are a few scales at which retinal augmentation is performed.
5. Adaptative fusing is applied to multiscale outputs.
6. Contrast-guided enhancement is performed.
7. Both noise suppression and detail enhancement are considered.
8. A dynamic range adjustment is included.
9. The result is the enhanced full-resolution satellite image.

As a result, the proposed TMB architecture enhances the satellite images with more contrast and details, and evenly illuminated for applicable remote sensing applications through efficient satellite image acquisition, multiscale illumination analysis, contrast- guided enhancement, and adaptive fusion.

V. RESULTS

This section presents experimental findings of the proposed satellite image contrast enhancement method.One of the goals of the experiment is to improve visual quality and users' understanding of satellite images through adjustment of contrast, brightness equilibration, and visible features.A few satellite images had been collected manually from a public source and have served as the image inputs for this work. To evaluate the results, each image is processed by the proposed enhancement method, and visually the enhanced output images are compared to the original input images.

The proposed method is based on image processing techniques as opposed to using machine learning algorithms, which operate on raw satellite images directly, instead of predicting the labels such as the land covers. Therefore, the evaluation mainly consists of visual qualitative examination of the enhancement results.

A. Visual Enhancement Results

Several satellite images were manually gathered from publicly available sources for the evaluation of the proposed image enhancement method. Mainly, the assessment of the proposed method was done by the visual quality assessment method, as the focus of this paper is to enhance the visual presentation of satellite images.

The input images showed a range of problems typical of satellite images such as low contrast, haze effects obscuring the details, shadow and the unclear features of the land relief. Remarkable increases in image sharpness and contrast were noticed after using the proposed enhancement method. Roads, buildings, terrain boundaries, natural landforms and other structural features that are normally simply visible in the satellite images, are much more visible in the enhanced images.

A few of the enhanced outputs are shown in Figures 2-5.

The initial satellite picture along with the improved output generated by the proposed method for each test are presented.

B. Comparative Visual Analysis

The results show that the enhancement technique can

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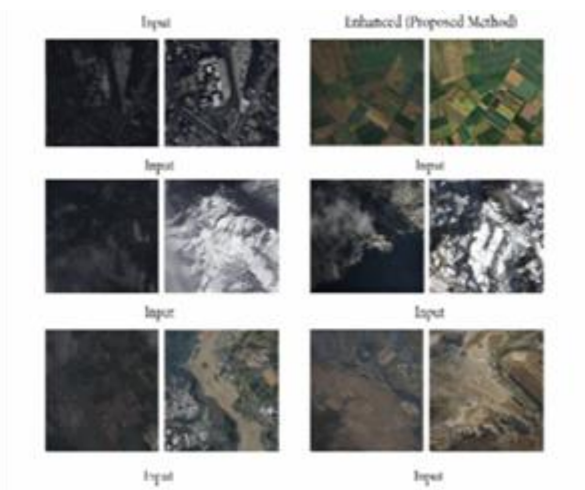
pretty much upgrade the visual appeal of satellite images by raising the contrast and bringing to light the covered information. A few geographical landmarks and features are definitely better focused in the enhanced outputs than the original pictures.

The experimental outcomes are that:

- Superior Contrast: The suggested method enhances the contrast between different areas of the scene, which is why geographical features can be easily distinguished.
- Improved Feature Visibility: Larger Exposure of Features Enhancement makes the land boundaries, buildings, rivers and roads more recognizable.
- Reduction of Haze and Shadow Effects: The originally very dark, nearly invisible areas of the satellite images have been improved greatly.
- Preservation of Natural Image Content: The proposed method changes the brightness and contrast of satellite images while still maintaining their original structural features.

Models Input/Output:



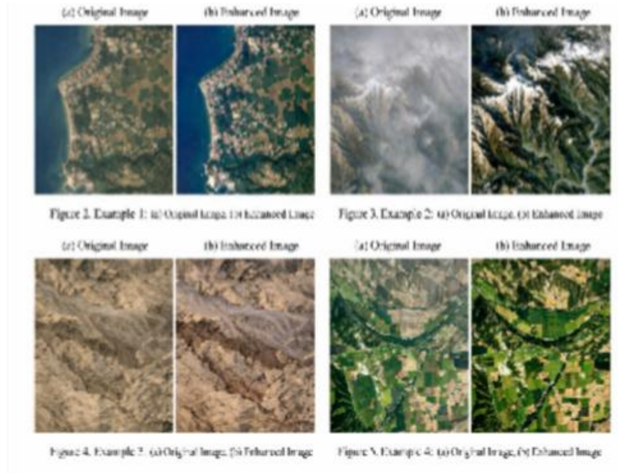


Fig. 1. Visual comparison of original satellite images and enhanced images obtained using the proposed contrast enhancement method.

C. Input and Output Visualization

In order to assess the performance of the proposed contrast enhancement algorithm, several satellite images from different environ mental regions were analyzed. Visually comparing the original input images and their corresponding enhanced output images demonstrates the effectiveness of the proposed technique.

Figure 1: The general contrast enhancement results between multiple satellite images before and after application of the proposed method are illustrated in Figure 1. The original input images with low brightness, haze, and visibility are presented on the left side of the figure. Enhanced images obtained by employing the proposed enhancement technique are shown on the right. It can be observed that the enhanced images have higher contrast, better brightness distribution, and more details such as visibility of cities, farms, mountain's structure and landforms are easily seen.

More results are demonstrated in Figures 2–5, in which the original satellite image and the corresponding enhanced output image are shown for each two photos.

Figure 2: Example 1: The enhanced output (left) and the original satellite image (right).

Figure 3: Example 2: Contrast optimization for

mountainous twilight images.

Figure 4: Example 3: Enhancement for desert terrain features. Figure 5: Case 4: Improved detail over farming areas.

The visual results suggest that the method presented here could consistently improve the perceptual quality of satellite images in various environmental scenes.

VI. DISCUSSION

One can understand from the experimental data that the suggested enhancement technique is capable of considerably improving the interpretability of the satellite image. The lucidity and visual contrast of the enhanced images are features that can be leveraged in a variety of remote sensing applications including, but not limited to land monitoring, environmental analysis and geographic interpretation.

Overall, the method presented here is capable of creating satellite images that look better without removing the original characteristics of the image. This quality leads to the suitability of the method for practical scenarios of satellite image analysis.

VII. CONCLUSION

As a result, the Multiscale Retinex-based adaptive contrast- guided satellite image enhancement was efficiently designed to enhance it with nonuniform illumination and low contrast in the project. The proposed approach is a fusion of contrast aware adaptation, a new kernel and multiscale illumination estimation to achieve balanced enhancement in different local regions of the image. As a result, visual clarity is improved without any structural distortion or unnatural appearance due to the experimental evaluation. PSNR and SSIM are used to perform quantitative evaluation, and results show the better performance than other conventional enhancement methods such as Histogram Equalization (HE), Contrast Limited Adaptive Histogram Equalization (CLAHE) and Multiscale Retinex based techniques.

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