AN IMPROVED TECHNIQUE FOR ENHANCEMENT OF SATELLITE IMAGE

By

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ABSTRACT

In the age of artificial intelligence, remote sensing and especially satellite imagery are gaining widespread interest among the computer science community in their efforts to enable machines to recognize their environment through satellite image classification. Imaging satellites provide images of Earth that are collected, analyzed, and processed for both civil and military purposes. Satellite images are an important source of data, captured by artificial satellites orbiting the Earth. These images are susceptible to noise and irregular illumination, which can affect their quality. This paper proposes an improved enhancement technique that increases the visual perception of the image while preserving its details. The proposed method uses image processing techniques with contrast enhancement to improve image quality. By enhancing contrast, this technique significantly benefits the creation of high-quality images. The effectiveness of the proposed method is evaluated using PSNR, entropy, and histogram analysis.

Keywords: Image Processing, Image Enhancement, Quality Measurements, Satellite Imaging.

INTRODUCTION

Satellite images, also known as Earth observation imagery, space-borne photography, or satellite photos, are pictures of Earth captured by imaging satellites operated by governments and businesses globally. Satellite imaging companies sell images by licensing them to entities such as Apple Maps and Google Maps. Satellite images function as indispensable tools for meteorologists, offering a comprehensive view of atmospheric phenomena from above. They provide invaluable insights into weather patterns, enabling forecasters to monitor and predict weather events accurately. Unlike data collected from ground stations, which is limited in coverage and scope, satellite imagery offers a global perspective, which is especially beneficial over vast oceanic regions where ground-based observations are sparse. By complementing traditional data sources, satellite images enhance our understanding of atmospheric dynamics and significantly bolster the precision of weather forecasting.

Satellite Types

Geostationary satellites allow meteorologists to view the weather as it develops since they observe the same area continuously. Three main types of satellite images are available:

- Visible
- Infrared
- Water Vapor

Visible Imagery: Visible satellite pictures can only be viewed during the day since clouds reflect light from the sun. In these images, clouds appear white, the ground is typically gray, and water is dark. In winter, snow-covered ground appears white, making it harder to distinguish from clouds. Looping images can aid in differentiation, as clouds will move while the snow remains stationary. Snow-covered ground can also be identified by looking for terrain features, such as rivers or lakes. Rivers will remain dark in the imagery as long as they are not frozen. If the rivers are not visible, they are probably covered by clouds. Visible imagery is also useful for observing thunderstorm clouds as they develop. Satellites can detect developing thunderstorms in their earliest stages before they are picked up by radar.

Infrared Imagery: Infrared satellites provide pictures of clouds day and night. Instead of using sunlight to reflect off the clouds, these satellites identify clouds by measuring the heat radiating from them. The sensors also measure the heat radiating from the surface of the Earth. Clouds are colder than land and water, so they are easily identified. Infrared imagery is useful for determining thunderstorm intensity; strong to severe thunderstorms typically have very cold tops. This imagery can also be used to identify fog and low clouds. The fog product combines two different infrared channels to detect fog and low clouds at night, which appear as dark areas on the imagery.

Water Vapor Imagery: Water vapor satellite images indicate the amount of moisture in the upper atmosphere (approximately 15,000 to 30,000 feet). The highest humidity appears as the whitest areas, while dry regions appear dark. Water vapor imagery is useful for indicating where heavy rain is possible, and thunderstorms can also develop under high moisture plumes.

Providing a Base Map for Reference

Highly detailed Otto imagery from high-resolution satellite data provides a pictorial representation of the area of interest and its surrounding regions. These geo-referenced maps offer a wealth of details to give a comprehensive view of the area. The base maps can be used for various purposes, such as transportation planning, site selection for new railways and airports, urban planning, property tax surveys, and mapping of urban zones, including residential, commercial, and industrial areas.

Land use/Land Covers Mapping

Satellite images are probably one of the quickest and most economical ways to create a land use/land cover map of an area. These images provide an accurate representation of the current state of land use. Figure 1 shows the object based image segmentation.

A change detection study using images of different vintages can reveal patterns of urban sprawl, changes in forest cover, and the extent of damage caused by floods or droughts (Maheswari & Afreen, 2022). With the wide range of commercially available remote sensing software, one can create highly accurate land use maps of any region from the comfort of their office or home, without the need for field visits.

Land use or clutter maps, along with other layers such as Digital Terrain Models (DTM), vector data (roads), and population data, are also used by telecom companies for network planning. These maps are available at resolutions of 20 to 50 meters for country or regional data, 5 to 10 meters for urban areas, and highly detailed 1 to 5 meters for 2D and 3D maps used in detailed LTE/5G planning. Figure 2 shows the digital globe.

3D GIS and City Models

High-resolution stereo satellite imagery (0.30 m to 0.50 m) has proven invaluable by providing cost-effective stereo images over expansive areas rapidly, surpassing aerial photography. Aerial photography requires significant permissions and sophisticated equipment for data acquisition.

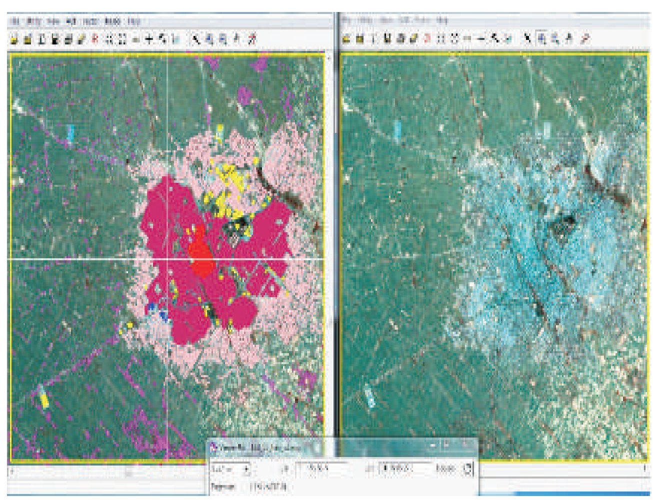

Figure 1. Object Based Image Segmentation

3D city models are digital representations of urban areas, encompassing terrain surfaces, buildings, vegetation, infrastructure, and landscape elements. These models provide intricate details essential for creating both two-dimensional and three-dimensional geo-referenced spatial data. 3D city models facilitate the presentation, exploration, analysis, and management of various tasks across numerous application domains. This data supports urban and rural planning departments, site selection for next-generation 5G network planning, and smart city applications such as drainage, sewerage, and water supply planning.

Applications in Mining

Satellite images with advanced hyperspectral ranges play a crucial role in the pre-feasibility and feasibility stages of mineral exploration. Offering a comprehensive overview, they provide vital insights into the mineral potential of targeted extraction areas. Integrating satellite remote sensing into GIS platforms helps geologists and mining companies efficiently map mineral potential zones, thereby saving valuable time. Spectral analysis of satellite image bands enables scientists to identify and map mineral availability using specific indicators, guiding focused geophysical, geochemical, and test drilling activities toward high-potential zones.

Planning for Disaster Mitigation

Satellite imagery, with its ability to repeatedly survey affected regions, proves invaluable in assessing the aftermath of natural disasters like floods, cyclones, earthquakes, and landslides, particularly in areas inaccessible during such crises. Offering rapid and precise data on disaster zones, satellite images play a crucial role in strategizing relief and rescue efforts. Moreover, they aid in identifying suitable locations for storm/flood shelters. By comparing pre and post-event imagery, the extent of damage wrought by catastrophic floods becomes vividly apparent.

Applications in Agriculture and Forestry

Satellite images play a crucial role in managing the world's agricultural resources, which are essential for feeding the ever-growing global population. Issues such as deforestation, desertification, and salinization due to over-irrigation, along with recurring droughts in rain-dependent regions, further challenge the availability of arable land. Utilizing remote sensing and GIS technologies offers solutions to enhance agricultural production and effectively manage farmlands by providing reliable data on resource types, quality, quantity, and location. Remote sensing studies enable accurate assessment of acreage, crop health monitoring, and yield estimation. Figure 3 shows the cultivated areas (Image Credit: Landsat image of Sunderban, NASA).

(Image Credit: Landsat image of Sunderban, NASA)

The utilization of satellite imagery and GIS presents a valuable opportunity to enhance current methods of acquiring and producing maps and resource data for forestry mapping. This is crucial for addressing threats such as forest fires, illegal logging, urban expansion, and infrastructure projects like dams and highways. This data is

Figure 2. Digital Globe

Figure 3. Circular Cultivated Areas

indispensable for making informed management decisions to safeguard this vital resource. In the image's upper section, the pink areas indicate the clearing of mangrove forests in the Sunderban Delta for agricultural purposes, posing a significant risk to the delicate mangrove ecosystem.

Monitoring Climate Change

Satellites, acting as the "eye in the sky," offer crucial visual evidence for monitoring polar ice caps. They provide undeniable proof of significant changes occurring in the Polar Regions, including the retreat of numerous glaciers due to rising temperatures. Similarly, satellite images document the encroachment of deserts into new areas, as well as widespread deforestation and forest fires worldwide, prompting governments and environmental agencies to take decisive action. The applications and benefits of satellite images are vast and immense. They have proven to be a reliable and cost-effective source of valuable data for scientists, planners, and decision-makers to monitor the Earth for the larger collective benefit of humankind. Figure 4 shows the operational land imager.

1. Literature Survey

Ahuja and Biday (2013); Kaur and Kaur (2017) Satellite image enhancement is a technique that is widely required in the field of satellite image processing to improve the visualization of features. Satellite images are captured from a very long distance, which means they often contain significant noise and distortion due to atmospheric barriers. After capturing the image, some radiometric and geometric corrections are performed,

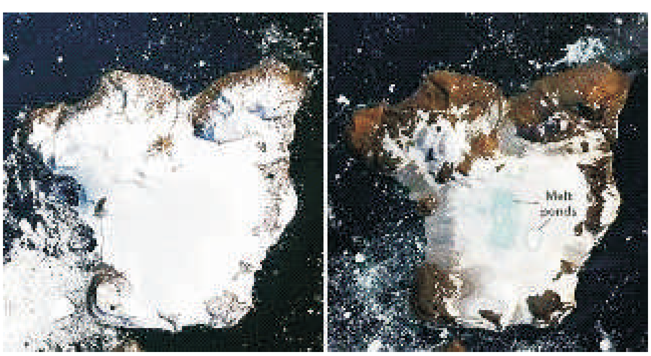

Figure 4. Operational Land Imager

but these are not always sufficient for all applications. It is crucial to enhance the restored image before using it. The main objective of this paper is to understand the terms related to the enhancement of satellite images. Image enhancement techniques are used to make satellite images more informative so that they can be readily interpreted by the human eye. Enhancement involves altering the appearance of an image in such a way that the information contained in the image is more easily interpreted visually.

Bajpai and Soni (2017) Satellite imagery is used in various research domains. These images often have significant quality issues, which can be improved using image enhancement algorithms in terms of contrast, brightness, and feature reduction from noise, among other aspects. These algorithms are employed to focus, sharpen, or smooth images to better exhibit and analyze their attributes. Therefore, the objective of image enhancement depends on the specific application. The aim of this paper is to provide a brief overview of image enhancement techniques that yield progressive and optimal results for remote-sensing satellite imagery. To achieve this, we evaluate various image enhancement algorithms that are currently popular for boosting image quality in several application areas of image processing.

Jadhav and Patil (2015) discuss the challenges in the field of image processing, specifically with satellite imaging. Satellite imaging presents significant challenges for researchers, and various satellite sensors are available that range from very low to high resolution for data collection. In this paper, a satellite image enhancement algorithm is proposed, which is based on interpolating the high-frequency subbands obtained through discrete wavelet transform (DWT) and the low-resolution input image. This method uses DWT and interpolation of high-frequency subband images into low-resolution input images. The sharpness of the image is enhanced by estimating the high-frequency subbands, and the inverse DWT is performed to reconstruct the resultant image. The paper presents and discusses visual and mathematical results using LANDSAT 8 data, comparing the proposed method with conventional and state-of-the-art resolution enhancement methods.

Chae et al. (2013) present an adaptive anti-aliasing algorithm based on the wavelet-Fourier transform and directionally adaptive wavelet shrinkage. The proposed anti-aliasing algorithm detects aliasing artifacts by analyzing the frequency characteristics of discrete wavelet transform (DWT) coefficients and then removes these artifacts by shrinking the transform coefficients in a directionally adaptive manner. Specifically, the algorithm analyzes the properties of the LH, HL, and HH subbands of the DWT and reduces aliasing artifacts in the LL subband by shrinking the coefficients in a patch-based adaptive manner. Meanwhile, aliasing artifacts in the LH, HL, and HH subbands are reduced using directional filtering. The resulting anti-aliased image is obtained by applying the inverse DWT. Experimental results show that the proposed algorithm efficiently reduces aliasing artifacts while preserving high-frequency image details. This anti-aliasing algorithm is suitable not only for mobile imaging systems but also for various applications in image restoration and multidimensional sampling.

Kundeti et al. (2013) proposed an effective resolution enhancement approach for images, including both satellite and standard images. This method utilizes DT-CWT and bicubic interpolation. The proposed method was tested on well-known benchmark images. Finally, the Peak Signal-to-Noise Ratio (PSNR) and visual results demonstrated that the proposed method performs at the state-of-the-art level for image resolution enhancement techniques.

Demirel and Anbarjafari (2009) propose a satellite image resolution enhancement technique which is based on the interpolation of high-frequency subband images obtained through the dual-tree complex wavelet transform (DTCWT). DT-CWT is used to decompose an input low-resolution satellite image into various subbands. Subsequently, the high-frequency subband images and the input image are interpolated and combined to generate a new high-resolution image using the inverse DT-CWT. The resolution enhancement is achieved through the directional selectivity provided by the CWT, where high-frequency subbands in six different directions contribute to the sharpness of high-frequency details, such as edges. The quantitative peak signal-to-noise ratio (PSNR) and visual results demonstrate the superiority of the proposed technique over conventional methods such as bucolic interpolation, wavelet zero padding, and Iran and Pele-based image resolution enhancement techniques.

2. Implementation

Maheswari and Kadapa (2022) describe image enhancement as the process of adjusting digital images to make them more suitable for display or further analysis. For example, image enhancement can involve removing noise, sharpening, or brightening an image, which makes it easier to identify key features. To improve satellite images, image enhancement techniques are used to focus on and highlight important features of the image. One such technique involves contrast enhancement, which adjusts the relative brightness and darkness of objects in the scene to improve their visibility. The contrast of an image can be changed by adjusting the intensity values, i.e., by mapping the input intensity values to new values to increase the contrast.

2.1 Block Diagram of Proposed Method

Image preprocessing refers to operations performed on images at the lowest level of abstraction. These operations do not increase the information content of the image; rather, they decrease it if entropy is considered a measure of information. Figure 5 shows the proposed method image preprocessing.

The aim of preprocessing is an improvement of the image data that suppresses undesired distortions or enhances some image features relevant for further processing and analysis tasks. The contrast enhancement technique plays a vital role in image processing by revealing information within the low dynamic range of a grayscale image. To improve image quality, operations such as contrast enhancement and noise reduction or removal are required. Contrast adjustment remaps image intensity values to the full display range of the data type. An image with good contrast shows sharp differences between black and white, while an image with poor contrast has intensity values limited to the middle portion

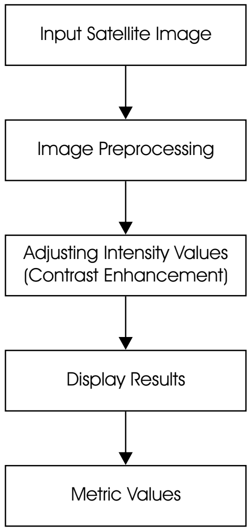

Figure 5. Proposed Method Image Preprocessing

of the range. An image with high contrast has intensity values that span the entire range [0, 255], making highlights appear brighter and shadows appear darker. Different functions primarily apply to grayscale images, but some can also be applied to color images.

3. Existing Method

The simplest type of enhancement is a linear contrast stretch. This involves identifying the lower and upper bounds from the histogram (usually the minimum and maximum brightness values in the image) and applying a transformation to stretch this range to fill the full range. A linear stretch uniformly expands this limited range to cover the entire range of values from 0 to 255. This enhances the contrast in the image with light-toned areas appearing lighter and dark areas appearing darker, making visual interpretation much easier.

3.1 Drawbacks of the Existing System

It sometimes causes over-enhancement in certain portions of the image.

Another problem with this method is that it also enhances the noise in the input image along with the image features.

Often, these methods produce an undesirable checkerboard effect on the enhanced images.

4. Proposed System

Real-time views of the Earth and its surroundings can be obtained through satellite images. The enormous constellation of remote sensing satellites orbiting the planet makes numerous applications for the benefit of humanity possible. Whether it's mapping the devastation left by destructive cyclones and earthquakes or studying more gradual morphological changes in a city's urban sprawl over time, satellite images provide a wealth of information to scientists, planners, and decision-makers in both the public and private sectors for effective policy and decision-making. Image enhancement is the process of adjusting images to make them more suitable for display or further analysis.

Conclusion

Satellite images are an extremely useful source of data for many different subjects. However, the quality of these images is often impacted by communication signal disturbances caused by various factors. In the proposed method, we use image processing techniques with contrast enhancement to improve the images. This contrast enhancement technique significantly supports the creation of high-quality images. The results are demonstrated by presenting the quality metrics of the enhanced images and a histogram of the enhanced images.

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