Project report on

CLAHE-Based Enhancement of Satellite Images

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Digital Image Processing

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Chapter 1: Introduction

Satellite imagery plays a crucial role in various remote sensing applications such as land use analysis, crop monitoring, water body detection, and environmental change assessment. However, satellite images often suffer from **poor contrast**, **uneven illumination**, and **low visibility of terrain features** due to atmospheric effects or sensor limitations.

To overcome these limitations, this project implements **Contrast Limited Adaptive Histogram Equalization (CLAHE)** and **RGB Histogram Equalization** to enhance satellite images. CLAHE improves local contrast and highlights subtle features, while RGB equalization balances color channels for a clearer and more detailed representation.

Chapter 2 - Objectives:

The primary objectives of this project are:

1. To enhance the visual quality of satellite images using CLAHE and RGB equalization.
2. To reveal hidden terrain details such as ridges, dunes, and surface roughness.
3. To improve the distinguishability between different land-cover classes.
4. To generate processed images suitable for classification, segmentation, and analysis tasks.

Chapter 3 – Literature Review:

Traditional image enhancement methods like global histogram equalization improve contrast uniformly but often lead to over-saturation or loss of local details.

CLAHE, on the other hand, divides the image into smaller tiles and applies localized histogram equalization with a clip limit to avoid noise amplification.

In recent years, CLAHE has been widely used in:

- Medical imaging (for X-ray and MRI enhancement)
- Remote sensing (for terrain feature enhancement)
- Agricultural monitoring (for vegetation index improvement)
- Preprocessing for deep learning models in geospatial analysis

Hence, CLAHE is a robust and effective method for enhancing high-resolution satellite images where both texture and tone preservation are important.

Chapter 4 – Methodology :

4.1 System Flow

1. **Input:** Satellite images collected from datasets or captured imagery.
2. **Color Conversion:** Convert the image from RGB to LAB color space.
3. **CLAHE Processing:** Apply CLAHE on the L (lightness) channel to enhance local contrast.
4. **RGB Equalization:** Perform histogram equalization on R, G, and B channels separately to normalize global tone.
5. **Merging:** Combine the processed channels to form the final enhanced image.
6. **Output:** Save and visualize enhanced images for analysis.

4.2 Algorithm

Step 1: Read input image

Step 2: Convert image to LAB color space

Step 3: Apply CLAHE on the L-channel

Step 4: Convert back to BGR color space

Step 5: Apply histogram equalization on each RGB channel

Step 6: Merge channels and save enhanced image

4.3 Tools and Libraries

Component	Description
Language	Python 3
Libraries	OpenCV, NumPy, Google Colab
Environment	Google Colab / Jupyter Notebook
Input Data	Satellite images (RGB, .jpg/.png format)
Output	Enhanced contrast images

4.4 Code Implementation

```
import cv2
import numpy as np
import os
from google.colab.patches import cv2_imshow

input_folder = '/content/images'
output_folder = '/content/drive/MyDrive/processed_imgs'
os.makedirs(output_folder, exist_ok=True)

def apply_clahe(image):
    lab = cv2.cvtColor(image, cv2.COLOR_BGR2LAB)
    clahe = cv2.createCLAHE(clipLimit=2.0, tileGridSize=(8,8))
    lab[:,:,0] = clahe.apply(lab[:,:,0])
    return cv2.cvtColor(lab, cv2.COLOR_LAB2BGR)
```

```
def apply_rgb_method(image):
    b,g,r = cv2.split(image)
    b = cv2.equalizeHist(b)
    g = cv2.equalizeHist(g)
    r = cv2.equalizeHist(r)
    return cv2.merge((b,g,r))

for filename in os.listdir(input_folder):
    if filename.lower().endswith(('.jpg','.png','.jpeg')):
        img = cv2.imread(os.path.join(input_folder, filename))
        enhanced = apply_rgb_method(apply_clahe(img))
        cv2.imwrite(os.path.join(output_folder, f"processed_{filename}"),
enhanced)
        print(f"Processed: {filename}")
```

Chapter 5 – Applications of CLAHE in Satellite Image Processing :

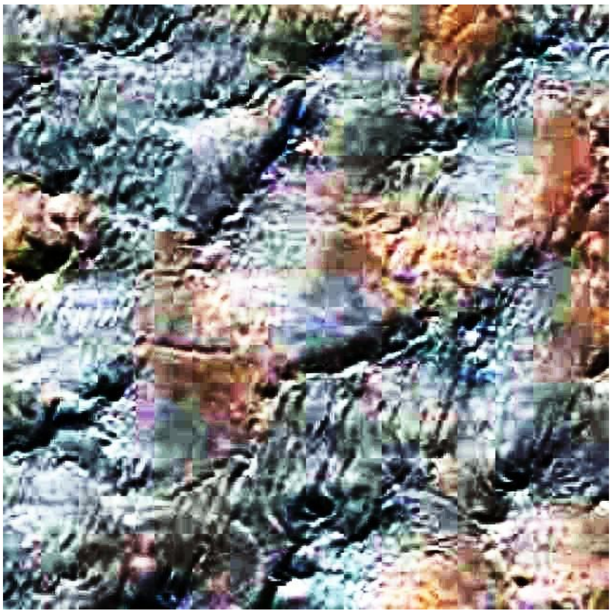
Application	Description
Land Cover Classification	Enhances contrast between vegetation, water, and soil for better classification accuracy.
Change Detection	Normalizes lighting variations between temporal images for accurate comparison.
Vegetation Analysis	Improves visibility of vegetation stress and crop boundaries.
Geological Mapping	Reveals subsurface formations and terrain roughness.
Water Body Detection	Enhances the distinction between water and land surfaces.
Disaster Monitoring	Highlights damaged areas in post-disaster imagery.

Chapter 6 – Results and Discussion:

6.1) Input and Output Image

a)

Input Image



Output Image

b)

Input Image

Output Image

6.2 Observations

- The enhanced image shows **improved local contrast**, especially in flat or low-texture regions.
- Fine details such as ridges, dunes, and surface gradients become more visible.
- Some false-color effects may appear due to RGB equalization, but

these can be tuned using CLAHE parameters.

- The method significantly improves the performance of **feature extraction** and **segmentation algorithms** applied afterward.

Chapter 6 – Conclusion:

This project successfully demonstrates the use of CLAHE and RGB Histogram Equalization for enhancing satellite imagery.

The method effectively improves local contrast and reveals hidden features, making it suitable for a wide range of remote sensing applications such as land cover mapping, vegetation analysis, and terrain classification.

The approach is computationally simple, efficient, and easy to integrate as a preprocessing module in advanced AI-based geospatial models.

Chapter 7 - References:

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