SAR Image Colorization Using Machine Learning (KNN)

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Abstract

This research explores the use of the K-Nearest Neighbors (KNN) algorithm for colorizing Synthetic Aperture Radar (SAR) images, which are typically monochromatic. SAR images, commonly used in remote sensing, are generally grayscale and lack the interpretive benefits that color images provide. By utilizing KNN within the LAB color space, this study achieves colorization by mapping grayscale intensities to chromatic color channels. This enhances the interpretability of SAR data, with applications in fields such as environmental monitoring, military surveillance, and geographic analysis. The datasets used in this project were sourced from the Bhoonidhi and ISRO websites, providing high-resolution SAR images essential for the colorization experiments.

1 Introduction

1.1 Overview of SAR Imaging

Synthetic Aperture Radar (SAR) is a remote sensing technology that captures high-resolution images by analyzing reflected radar signals. SAR imaging is used in various fields, including geospatial studies, environmental monitoring, and disaster management. SAR captures surface details effectively but is limited to grayscale representations, which restricts the depth of information that can be interpreted visually.

1.2 Motivation for Colorizing SAR Images

The lack of color in SAR images makes it difficult to differentiate between certain features, especially when images are being analyzed for ecological monitoring, urban development, or military applications. Adding color to SAR images improves interpretation by allowing users to differentiate between natural and man-made structures, vegetation types, and water bodies. Traditional methods for adding color can be computationally intensive, but machine learning methods such as KNN offer a simplified approach that yields accurate and visually useful results.

2 Methodology

2.1 Objective

The goal of this study is to use KNN for colorizing grayscale SAR images, focusing on the LAB color space. The LAB color space allows us to separate lightness from color information, which is beneficial when colorizing grayscale images since we only need to predict the A and B channels (color information).

2.2 LAB Color Space and KNN

The LAB color space is particularly suitable for image processing tasks where color and luminance need to be separated. The conversion process from RGB to LAB involves multiple transformations:

RGB to XYZ Conversion:

$$\begin{aligned} X &= 0.4124 \times R + 0.3576 \times G + 0.1805 \times B \\ Y &= 0.2126 \times R + 0.7152 \times G + 0.0722 \times B \\ Z &= 0.0193 \times R + 0.1192 \times G + 0.9505 \times B \end{aligned} \tag{1}$$

XYZ to LAB Conversion:

Given X, Y, and Z, the LAB components are calculated as:

$$L = 116 \times f(Y/Y_n) - 16 \tag{2}$$

$$A = 500 \times (f(X/X_n) - f(Y/Y_n)) \tag{3}$$

$$B = 200 \times (f(Y/Y_n) - f(Z/Z_n)) \tag{4}$$

where $f(t)$ is defined as:

$$f(t) = \begin{cases} t^{1/3} & \text{if } t > \delta \\ \frac{t}{3\delta^2} + \frac{4}{29} & \text{if } t \leq \delta \end{cases}$$

with $\delta = 6/29$.

2.3 KNN-Based Colorization

KNN colorizes SAR images by finding nearest-neighbor pixels in reference color images and applying the corresponding color values. For each pixel intensity x_i in the grayscale SAR image, the KNN algorithm finds the nearest neighbors in the reference image and assigns the average A and B color values.

KNN Prediction Equations:

For a pixel x_i with intensity L_i, the predicted A and B values are:

$$\hat{A}_i = \frac{1}{k} \sum_{j \in N_k(x_i)} A_j \tag{5}$$

$$\hat{B}_i = \frac{1}{k} \sum_{j \in N_k(x_i)} B_j \tag{6}$$

where $N_k(x_i)$ denotes the k nearest neighbors of x_i.

2.4 Steps in the Colorization Process

The process includes the following steps:

1. **Load the Grayscale SAR Image:** Convert the SAR image's luminance to the LAB model's L-channel.

2. **Reference Color Images:** Load reference color images, which provide the chromatic data for KNN.

3. **KNN Model Training:** Train the KNN model on the LAB values from the reference images, using the L channel as input and predicting the A and B channels.

4. **Color Reconstruction:** Merge the L channel of the SAR image with the predicted A and B channels to form a colorized image.

3 Code Walkthrough

This section provides a simplified Python code for implementing the KNN-based SAR colorization process.

```
import cv2
import numpy as np
from sklearn.neighbors import KNeighborsClassifier

def colorize_image_knn(grayscale_image, reference_images):
    # Convert grayscale image to LAB color space
    l_channel = cv2.cvtColor(grayscale_image, cv2.COLOR_GRAY2LAB)[:, :, 0]
    a_channel, b_channel = [], []

    # Train KNN model on reference LAB color values
    knn = KNeighborsClassifier(n_neighbors=5)
    for ref_img in reference_images:
        lab_image = cv2.cvtColor(ref_img, cv2.COLOR_BGR2LAB)
        l, a, b = cv2.split(lab_image)
```

```
        knn.fit(l.reshape(-1, 1), np.c_[a.reshape(-1), b.reshape(-1)])

    # Predict color channels using KNN
    a_pred, b_pred = knn.predict(l_channel.flatten().reshape(-1, 1)).T
    color_image = cv2.merge((l_channel, a_pred.reshape(l_channel.shape),
                             b_pred.reshape(l_channel.shape)))
    return cv2.cvtColor(color_image, cv2.COLOR_LAB2BGR)
```

4 Results

4.1 Input and Output Comparison

Below are comparisons of the original grayscale SAR images and their colorized counterparts. This showcases the impact of KNN-based colorization on SAR image interpretability.

Figure 1: Input Grayscale SAR Image

Figure 2: Output Colorized SAR Image Using KNN

5 Applications

This section highlights potential applications of SAR image colorization.

5.1 Environmental Monitoring

Colorized SAR images help track environmental changes, detect deforestation, and monitor water resources by making natural features more distinguishable.

5.2 Remote Sensing and Land Use

Remote sensing benefits from colorized SAR images, enabling clearer classification of vegetation types, urban areas, and water bodies for land use planning.

5.3 Military and Defense

SAR imagery is widely used in military surveillance. Colorization enhances image readability, allowing faster terrain assessment and identification of key features.

6 Dataset References

The dataset for this project was obtained from:

- Bhoonidhi (ISRO's Geospatial Data Portal): `https://bhoonidhi.nrsc.gov.in`
- ISRO Website: `https://www.isro.gov.in`

7 Conclusion

This study demonstrates that KNN-based colorization of SAR images can significantly enhance interpretability, making SAR imagery a more valuable tool in fields such as remote sensing and environmental monitoring.

8 Acknowledgments

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