Machine Learning

Project Report

Github Link: https://github.com/nishant9083/ColorSAR

Full name: Aditya Bajpai	**ID:** 12240030
Full name: Nishant Verma	**ID:** 12241170
Full name: Nishchay Rajput	**ID:** 12241180
Full name: Ojus Goel	**ID:** 12241190
Full name: Patel Janmay Gaurav	**ID:** 12241240

Project Overview

This project aims to develop a deep learning model for colorizing grayscale Synthetic Aperture Radar (SAR) images. SAR images are typically represented in grayscale and lack the natural color information present in standard optical images. Our project enhances the interpretability of these images by converting them into colorized versions, which are useful for applications such as geological studies, environmental monitoring, and surface feature analysis.

What are SAR Images?

Synthetic Aperture Radar (SAR) images are produced by radar systems that utilize microwave signals to create detailed images of the Earth's surface. Unlike traditional optical imaging, SAR operates independently of sunlight and can penetrate through clouds, providing valuable data for various remote sensing applications. However, SAR images are generally monochromatic and do not convey color information, which can limit their usability in certain analyses. Colorization can help reveal features that are not easily distinguishable in grayscale images, improving interpretability and analysis.

Tasks and Milestones

Load and Slice Images into Patches

- **Task :** Loading SAR images from the dataset and dividing them into smaller patches
- **Milestone :** Created image patches from full-sized SAR images, allowing the model to focus on localized details for improved colorization accuracy.

Convert Patches to Lab Color Space

- **Task :** Converting the grayscale image patches from RGB to Lab color space.
- **Milestone :** Successfully transformed the image data into Lab color space, setting up the model for predicting the a and b color channels.

Combine and Loading Data

- **Task :** Merging processed image patches and loading them in batches for training.
- **Milestone :** Efficiently combined and prepared data batches, optimizing memory usage and ensuring smooth training performance.

Loading Data in Batches

- **Task :** Data fetching and loading in mini-batches to feed into the neural network.
- **Milestone :** Optimized data pipeline for efficient loading of images, ensuring smooth training without bottlenecks.

Implementing the Encoder

- **Task :** Designing and building the encoder to extract meaningful spatial and feature information from grayscale SAR images.
- **Milestone :** Completed a functional encoder architecture that can effectively capture and compress image features.

Implementing the Decoder

- **Task :** Developing the decoder to map the encoded features to the corresponding a and b color channels in Lab color space.
- **Milestone :** Successfully implemented the decoder, enabling the reconstruction of colorized images by predicting the chromatic components of the grayscale images.

Taining

- **Task :** Training the deep learning model with the encoder-decoder architecture using the preprocessed image data.
- **Milestone :** Completed multiple iterations of training, adjusting hyperparameters to improve model accuracy and reduce loss.

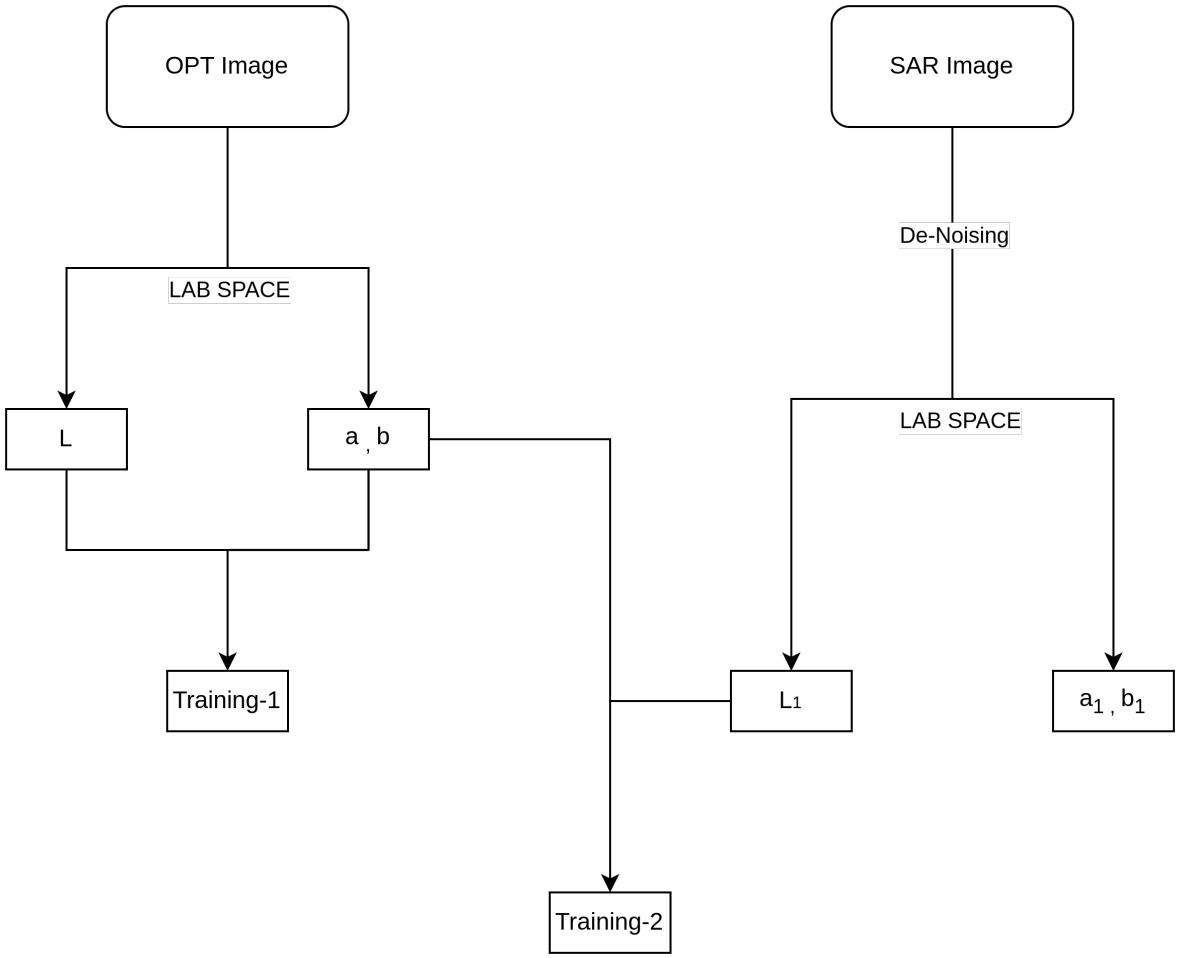
Prediction

- **Task :** Generating predictions for the colorized images using the trained model.
- **Milestone :** Produced colorized outputs from the SAR grayscale images, successfully mapping grayscale to the corresponding color space.

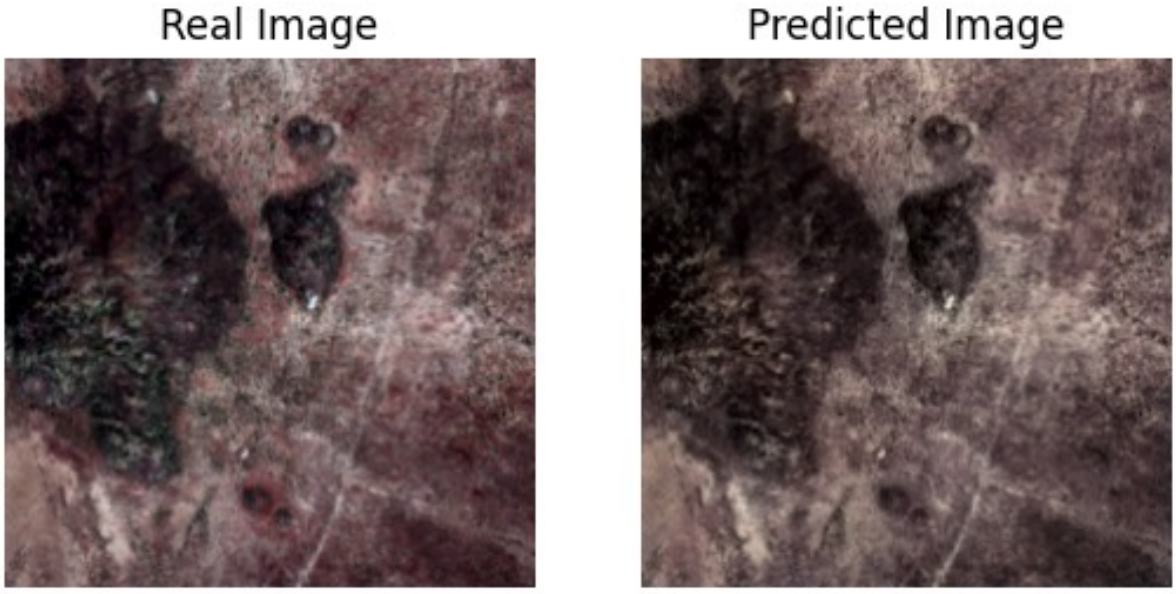
Evaluation

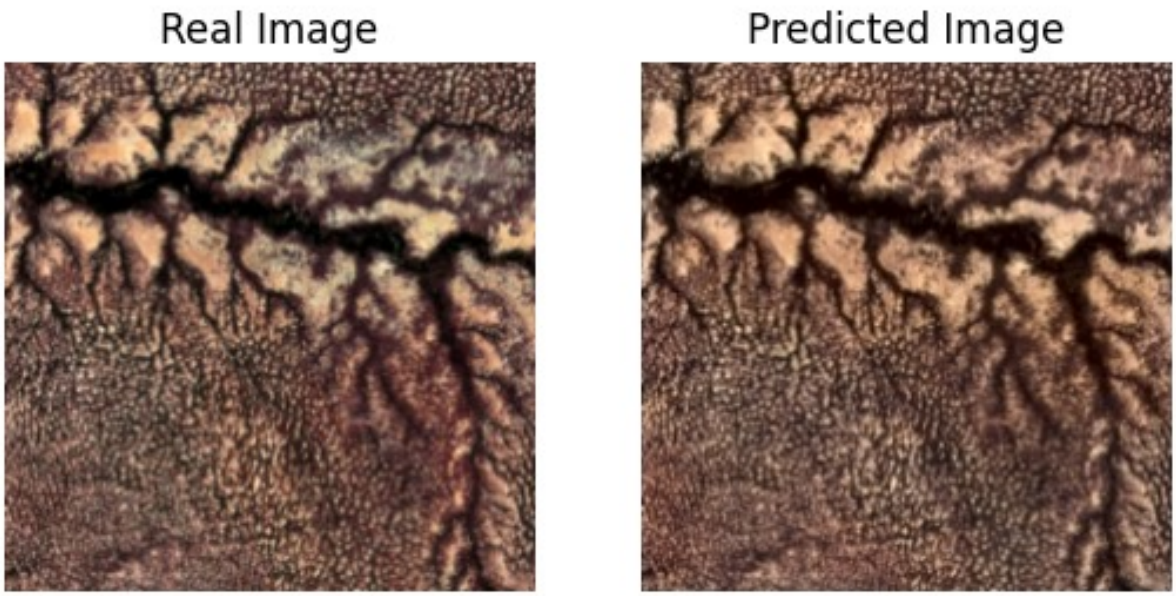
- **Task :** Evaluating the performance of the model using predefined metrics.
- **Milestone :** Assessed the quality and accuracy of the colorized images through evaluation metrics, ensuring that the results meet the project's objectives.

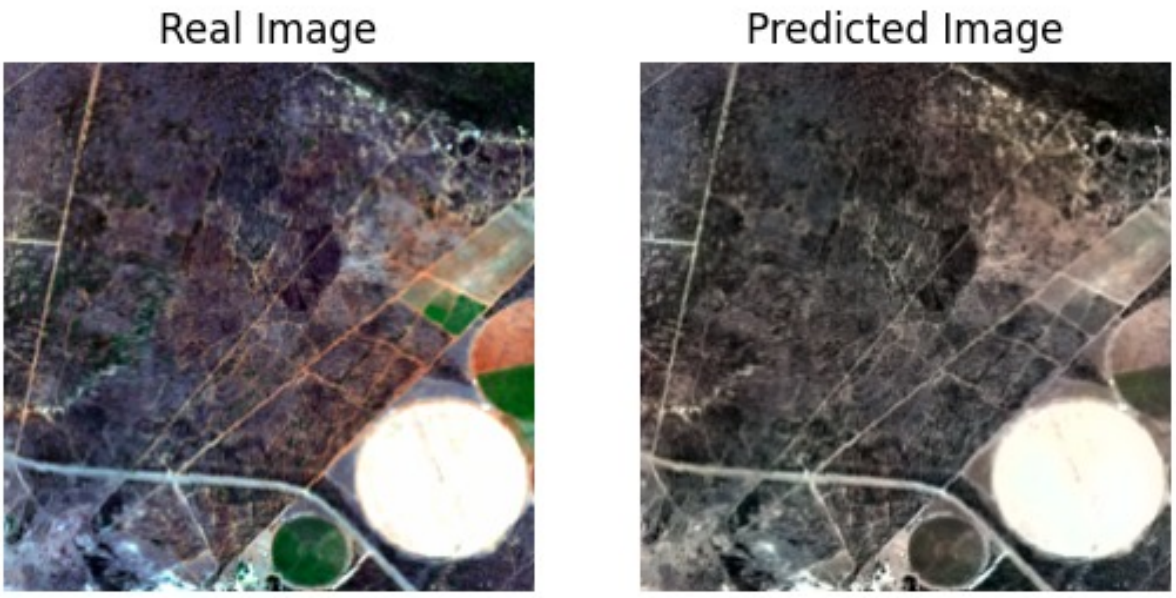
Workflow


OPT Image
SAR Image
De-Noising
LAB SPACE
LAB SPACE
L
a , b
Training-1
L1
a1 , b1
Training-2

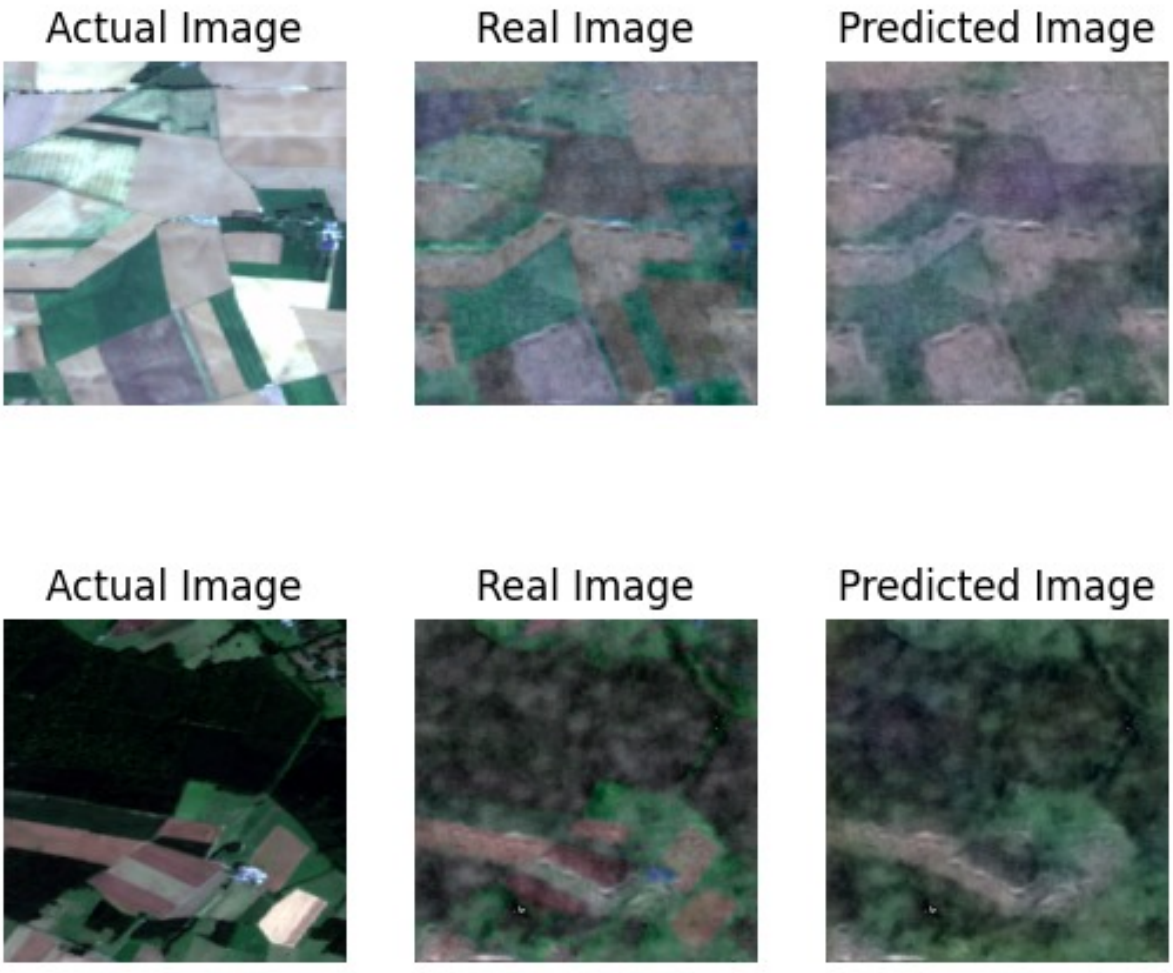
Training - 1 Result







Training - 2 Result



Explanation:

In this section, we compare the results of Training-1 and Training-2 results. Each model has been evaluated based on its performance in colorizing the SAR images. Below are the images produced by each model, showcasing the differences in colorization quality and accuracy.

Training 1: Trained on **L** and **AB Channels** of Original Color SAR Images This model was trained using both the **L (luminance)** and **AB (chrominance)** channels of **original color SAR** images as input-output pairs. As a result, the colorization output is highly accurate, demonstrating that this model effectively captures the underlying color information. The successful performance in this model proves the efficacy of the colorization approach.

Training 2: Trained on **L Channel** of Noisy, **Uncolored SAR Images** (Post-Denoising) with **AB Channel** of Original Color SAR Images In this model, training was conducted on the **L channel** of noisy, uncolored **SAR images** after applying denoising, combined with the **AB channel** of original color **SAR images** as input-output pairs. Consequently, while the color prediction remains fairly good, the overall results do not match the original due to the noise present in the **L channel**. This noise has impacted the preservation of structural definition in the images, leading to less accurate representations compared to Model 1.

Comparison Summary: Training-1 results demonstrates superior color accuracy due to the use of original color data, effectively proving the robustness of the colorization model. Training-2, while showing decent color predictions, suffers from structural fidelity issues caused by noise in the luminance channel, indicating that further refinement in denoising processes may be necessary for future iterations.

Future Deliverables

In the final phase of the project, one of the primary goals is to improve the denoising process. Although the team has implemented initial denoising techniques, further refinement is needed to reduce noise in the SAR images more effectively. This enhancement will result

in clearer inputs, leading to more precise predictions of the color channels, and ultimately, more accurate and visually appealing colorized images. The evaluation phase will also be extended in this final stage. While initial evaluations have been conducted, additional metrics will be employed to provide a more comprehensive assessment of the model's performance. Visual inspections will be carried out alongside the quantitative metrics to ensure that the colorized images meet the expected standards in terms of both accuracy and aesthetics. Finally, after all these improvements, the team will generate the final set of colorized SAR images. This will include:

- **Enhanced denoising** for cleaner, noise-free images.
- **Extended evaluation** with both statistical metrics and visual checks.
- **Final predictions** to produce the full dataset of high-quality colorized SAR images.

These tasks will ensure that the final deliverables of the project meet the objectives of producing clear and interpretably colorized SAR images suitable for applications like environmental monitoring and geological studies.

Contributions

Aditya Bajpai

Worked on defining and implementing the evaluation metrics that were used to assess the accuracy and quality of the colorized images. These metrics were designed to compare the model's predictions to the ground truth, ensuring the colorization was both realistic and consistent. His contributions ensured that the results of the model were properly quantified and validated.

Nishant Verma

Responsible for designing and implementing the encoder and decoder components of the colorization model. The encoder played a critical role in extracting important features from the grayscale SAR images, allowing the model to capture underlying spatial and texture information. The decoder, on the other hand, was instrumental in mapping these extracted features to the corresponding a and b channels in the Lab color space, which represent the chromaticity information. This step was essential for reconstructing the colorized images from the grayscale input. This architecture ensured that the model effectively captured and transferred spatial, texture, and color information during the training process, leading to accurate and realistic colorization of SAR images.

Nishchay Rajput

Gathering and pre-processing the SAR images to ensure they were suitable for the colorization model. This step was crucial as it set the foundation for the subsequent phases of the project, including training and evaluation. The work included tasks like data normalization, resizing, and augmentation to enhance the dataset for better performance.

Ojus Goel

Led the training and prediction stages of the model. Implemented the deep learning architecture, fine-tuned hyperparameters, and ensured that the model learned to map grayscale SAR images to colorized outputs. Also performed predictions on the dataset, generating colorized versions of the SAR images after the training phase was completed.

Patel Janmay Gaurav

Responsible for converting the image data into the appropriate format for colorization by performing the conversion to Lab color space, which is more suitable for image processing tasks. Additionally,handled patching, a technique used to divide the images into smaller sections (patches), allowing the model to focus on finer details during training and improving the accuracy of the colorization process.