Assignment 3: Group Research Project

Title: Application of CNN Models to Remote Sensing Using Satellite Imagery
Problem Focus: Land Cover Classification using EuroSAT
Module: CO3113/CO7113 – AI For Space (Group 8)
Submission Deadline: 28/04/2025 17:00hrs

Abstract

This is a research study that explores the application of Convolutional Neural Networks (CNNs) in remote sensing to classify land cover type. We utilized the EuroSAT dataset, which was derived from Sentinel-2 satellite images, consisting of variety land cover classes spread across Europe. We utilized a ResNet-18 architecture with transfer learning and fine-tuned the network to accomplish our intended classification. The process involved large-scale pre-processing, training, and testing of the model and analysis using standard measures like accuracy, precision, recall, F1-score, and confusion matrix plot. The end model achieved approximately 94% accuracy, demonstrating the effectiveness of CNNs for satellite image classification.

Introduction

Remote sensing is a crucial element in the study of the Earth's surface by providing homogeneous, large-scale observational data. Having the ability to automatically map land cover classes from satellite images has enormous applications in agriculture, urban planning, disaster relief, and environmental management. The procedures were traditionally reliant on manual interpretation or conventional machine learning. With deep learning, and more importantly Convolutional Neural Networks (CNNs), the precision could be increased while automating it at scale.

In this project, we address the issue of land cover classification using the EuroSAT dataset. The objective is to classify satellite images into ten different land cover classes using deep learning techniques, specifically by implementing transfer learning on a pre-trained ResNet-18 model. This effort not only highlights the power of CNNs but also demonstrates how transfer learning enables effective reuse of knowledge across different domains.

Literature Review

In recent times, there has been a strong synergy between recent advancements in deep learning and remote sensing. Helber et al. introduced the EuroSAT benchmark, showing CNNs pre-trained from big training datasets such as ImageNet could well be fine-tuned for land cover and land use classification. Studies show transfer learning significantly improves

performance, especially when available labeled satellite images are relatively very small in number compared to the natural image set.
Besides, research on network architectures including MobileNet, SqueezeNet, and EfficientNet has shown that lightweight models can achieve competitive performance with lower computational expenses. Data augmentation methods based on random cropping, flipping, and adjusting brightness also increase model robustness, especially under conditions of varying atmospheric and seasonal effects in satellite images.

Methodology

Problem Definition

The goal was to classify image patches into one of ten land cover classes, using a supervised learning approach.

Dataset

Name: EuroSAT
Source: Sentinel-2 imagery
Classes: Annual Crop, Forest, Herbaceous Vegetation, Highway, Industrial, Pasture, Permanent Crop, Residential, River, Sea Lake
Image Size: 64×64 pixels, RGB bands only
Total Samples: ~27,000 images

Pre-processing

- Images resized from 64×64 to 224×224 to fit ResNet input size.
- Normalization done using ImageNet mean and standard deviation.
- Dataset split into 70% training, 15% validation, 15% testing sets.

Model Architecture

Base Model: ResNet-18
Pre-training: ImageNet weights
Adjustment: The last fully connected layer replaced to output 10 classes.
Loss Function: CrossEntropyLoss
Optimizer: Adam (learning rate: 0.001)
Training: 10 epochs, batch size of 64.

Results and Analysis

Training Progress

10-epoch training brought significant improvement:

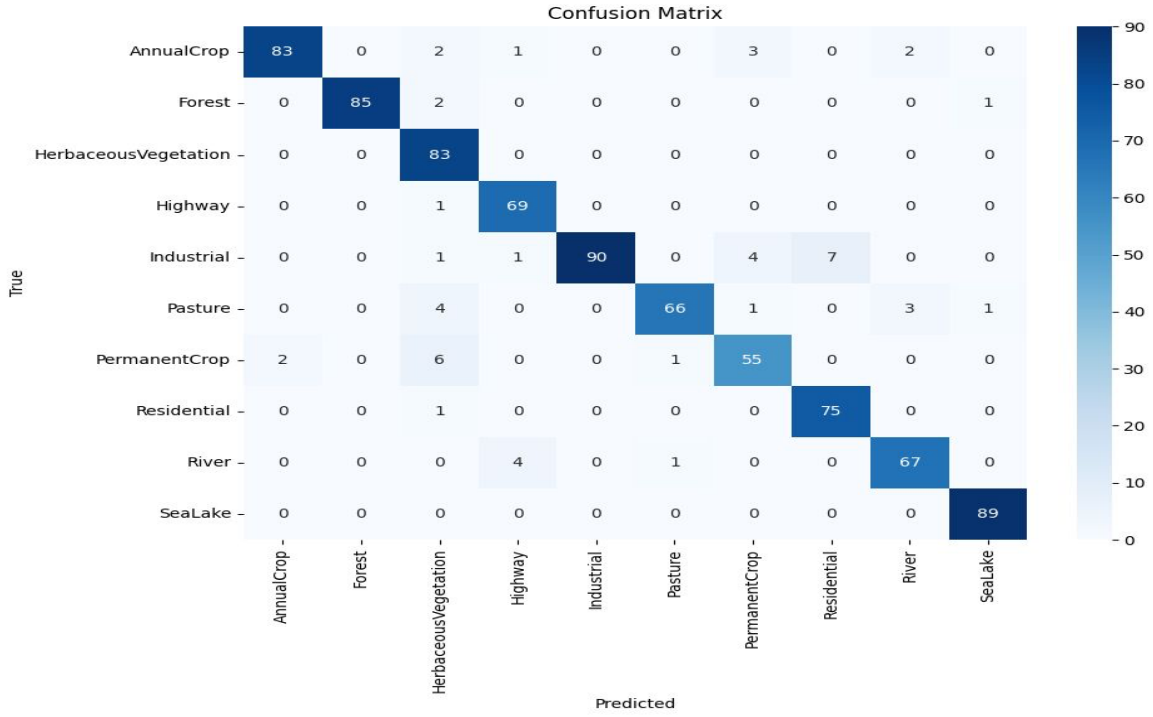
- **Epoch 1: Train Acc: 79.36%, Val Acc: 73.58%**
- **Epoch 5: Train Acc: 90.90%, Val Acc: 91.11%**
- **Epoch 10: Train Acc: 93.54%, Val Acc: 94.69%**

The training and validation curves showed steady improvement, with minor fluctuations typical in deep learning pipelines.

Final Performance

- **Overall Test Accuracy:** 94%
- **Macro Average Precision:** 94%
- **Macro Average Recall:** 94%
- **Macro Average F1-score:** 94%

All macro-averaged metrics, including Precision, Recall, and F1-score, converged around 94%, indicating that the model generalized well across all land cover classes without favouring any particular category.



Excellent diagonal dominance in the confusion matrix verified good classification ability. Forest, Sea Lake, and Residential classes possessed almost perfect precision and recall, while some slight confusion was present among Permanent Crop and Pasture, likely due to visual similarity on satellite imagery.

Discussion

Our results verify the effectiveness of CNNs combined with transfer learning for remote sensing classification. By fine-tuning ResNet-18, we leveraged deep hierarchical features learned on natural images and transferred them effectively to satellite images.

Training for more than 10 epochs allowed the model to generalize more effectively without overfitting, as evidenced by the high validation accuracy and flat loss curves.

Minor class misclassifications suggest room for improvement through techniques like focal loss, more aggressive data augmentation, or use of deeper architectures like ResNet-50 or DenseNet.

Conclusion

The project is a success in demonstrating the effectiveness of CNN-based transfer learning for satellite image classification. Using the EuroSAT dataset and ResNet-18 architecture, we have achieved a high classification accuracy of ~94%, with very good generalization across different land cover classes.

Future research can explore more intricate networks, ensemble methods, and semi-supervised learning techniques to further improve the classification performance, especially for visually similar classes.

References

- Helber, P. et al., EuroSAT: A Novel Dataset and Deep Learning Benchmark for Land Use and Land Cover Classification (2019)
- PyTorch Documentation: https://pytorch.org/
- Torchvision Models: https://pytorch.org/vision/stable/models.html

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Contributor

- Shreyash Wankhade (ssw14@student.le.ac.uk)
- Satyawan Singh (ss1738@student.le.ac.uk)