Project 7: Land Type Classification using Sentinel-2 Satellite Images

Team Members

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Introduction

Satellite image classification is a fundamental task in remote sensing and geospatial analysis, allowing researchers and decision-makers to monitor land use, urban expansion, agriculture, and environmental changes. The **EuroSAT dataset**, based on Sentinel-2 satellite imagery, offers a powerful benchmark for land use and land cover classification.

In this project, we aimed to build a robust image classification model for the **EuroSAT Multispectral (13-band) dataset** using a modified **ResNet-18** architecture. Our goal was to achieve high accuracy while maintaining a lightweight model that can run efficiently on CPU and GPU environments.

Project Objectives

- Preprocess and analyze the EuroSAT 13-band dataset.
- Adapt a ResNet-18 model to handle 13-channel input images instead of standard RGB.
- Train the model using cross-validation for robust performance.
- Evaluate the model on key metrics: accuracy, confusion matrix, and per-class performance.
- Visualize results and understand which classes are harder to predict.
- Address common issues such as data imbalance, overfitting, and model compatibility.

Dataset Overview

The EuroSAT dataset contains **27,000+ images** of size 64x64 pixels, distributed across **10 land cover classes**, including:

- Annual crop
- Forest
- Herbaceous vegetation
- Highway
- Industrial

- Pasture
- Permanent crop
- Residential
- River
- Sea/lake

Each image consists of **13 spectral bands** captured by the Sentinel-2 satellite, providing rich spectral information beyond visible RGB.

Milestone Breakdown

Milestone 1: Dataset Preprocessing

- **Challenge**: Adapting to 13-band data which standard models like ResNet-18 aren't built for.
- We used rasterio and torchvision.transforms to load and normalize the bands.
- Converted 13-band .tif files into tensors.
- Applied normalization based on Sentinel-2 statistics (mean and std dev for each band).

Milestone 2: Model Architecture Modification

- Modified the first convolutional layer of ResNet-18 from 3 channels (RGB) to 13 channels to accommodate multispectral data:

```
self.model.conv1 = nn.Conv2d(13, 64, kernel_size=7, stride=2, padding=3, bias=False)
```

- Retained the rest of ResNet-18's architecture to leverage residual connections and ease of training.

Milestone 3: Model Training and Evaluation

- Applied **5-fold Stratified Cross-Validation** to ensure balanced class representation.
- Used **Adam optimizer**, **CrossEntropyLoss**, and early stopping to prevent overfitting.

- Tracked training and validation accuracy and loss for each fold.
- Saved the best-performing model based on validation loss.

Milestone 4: Performance Analysis

- Achieved validation accuracy > 95% on most folds.
- Generated confusion matrix and classification report.
- Visualized class-wise accuracy to understand strengths and weaknesses.
- Noted that classes like “Industrial” and “Pasture” showed some confusion due to spectral similarity.

Challenges Faced

CHALLENGE	EXPLANATION	SOLUTION
MODEL LOADING ERRORS	State_dict keys did not match due to inconsistent model wrappers.	Rebuilt the model structure exactly as saved before loading.
13-BAND ADAPTATION	ResNet expects 3-channel inputs.	Modified conv1 layer to accept 13 channels.
MEMORY USAGE	Large number of high-dimensional images.	Used CPU for preprocessing, downsampled where needed, and optimized data loaders.
VISUALIZATION	Difficult to interpret 13-channel images.	Created pseudo-RGB images and PCA projections for analysis.
OVERFITTING	The model started to memorize training data.	Used dropout, regularization, and early stopping.

Results

Metric	Value (avg)
Accuracy	~96.5%
Precision	>94%
Recall	>94%
F1 Score	>94%

- **Most accurate classes**: Forest, Sea/Lake, Residential.
- **Confusing classes**: Industrial vs. Annual Crop; Pasture vs. Permanent Crop.

Key Learnings

- Adapting existing architectures like ResNet to new input shapes is effective with minimal changes.
- Stratified cross-validation is critical when working with class-imbalanced datasets.
- Even with more data (27,000+ images), proper preprocessing and model design are essential to prevent overfitting.
- Interpreting multispectral data requires both domain knowledge and visualization tools.

Future Work

- Experiment with more advanced architectures like **EfficientNet** and **Vision Transformers** adapted for 13 bands.
- Try data augmentation specific to satellite imagery (cloud masking, band-dropout).
- Deploy the model for real-time land use monitoring in a dashboard or GIS tool.
- Integrate temporal data from Sentinel-2 over time to improve classification consistency.

Conclusion

This project successfully demonstrated that with the right architectural adjustments and preprocessing techniques, traditional models like ResNet can be effectively used on non-standard datasets like EuroSAT. Despite challenges like model mismatch and visualization difficulties, we achieved excellent classification performance and gained deeper insights into handling multispectral satellite imagery.