Research project

1. Project Overview

Data cubes enable efficient access, querying, and analysis of large spatiotemporal satellite image archives. However, their accuracy and reliability depend heavily on the quality of spatial alignment between images (coregistration) and the ability to classify land surfaces under uncertainty. This project focuses on developing advanced techniques for **image coregistration** and **fuzzy classification** that will enhance the spatial consistency and thematic accuracy of Earth observation data cubes.

2. Objectives

1. **Develop a robust image coregistration workflow** to harmonize multi-sensor and multi-temporal satellite imagery.
2. **Implement fuzzy classification methods** to improve land-cover mapping and uncertainty handling within data cubes.
3. **Integrate both modules** into an analysis-ready data cube architecture.
4. **Validate and assess performance** using case studies on land-use/land-cover dynamics.

3. Methodology

- **Image Coregistration:**
    - Use feature-based and intensity-based approaches (SIFT, SURF, RANSAC, mutual information).
    - Evaluate alignment accuracy using geometric and statistical metrics.
    - Apply corrections to multi-temporal and multimodal datasets (optical + SAR).
- **Fuzzy Classification:**
    - Apply fuzzy c-means and rule-based fuzzy logic for soft classification.
    - Define membership functions for land-cover categories.
    - Generate uncertainty surfaces and compare with traditional classifiers.
- **Data Cube Integration:**
    - Incorporate aligned imagery and classification layers into a spatial-temporal data cube.
    - Use open standards (STAC/ODC) for indexing and metadata.
- **Validation:**
    - Conduct case studies (e.g., vegetation dynamics, surface water changes).
    - Use accuracy metrics, fuzzy confusion matrices, and uncertainty quantification.

4. Expected Outcomes

- High-accuracy, multi-temporal **coregistered datasets** ready for cube ingestion.
- A functional **fuzzy classification module** producing soft and hard land-cover maps.
- An integrated **prototype data cube** supporting advanced environmental analysis.
- Scientific outputs including documentation, reproducible scripts, and a manuscript draft.

5. Impact

The project will deliver enhanced spatial consistency and improved classification reliability in data cubes, enabling better environmental monitoring, more accurate change detection, and more robust geospatial decision-support systems.

Activity plan

Quarter 1 (Months 1–3): Setup & Coregistration Framework

- Identify datasets (Sentinel-1/2, Landsat) and select reference scenes.
- Review coregistration techniques and select suitable algorithms.
- Build preprocessing workflow (geometric correction, resampling).
- Begin implementation of feature- and intensity-based coregistration methods.

Quarter 2 (Months 4–6): Coregistration Implementation & Evaluation

- Run multi-temporal and multi-sensor coregistration experiments.
- Measure alignment accuracy using RMSE, control points, and overlay checks.
- Refine algorithms for challenging cases (terrain, clouds, SAR–optical alignment).
- Prepare coregistered datasets for downstream classification and cube integration.

Quarter 3 (Months 7–9): Fuzzy Classification Development

- Review fuzzy classification approaches and define target land-cover categories.
- Implement fuzzy c-means and membership functions.
- Generate preliminary classification maps for selected test areas.
- Compare fuzzy outputs with traditional classifiers (e.g., Random Forest).

Quarter 4 (Months 10–12): Classification Optimization & Integration

- Optimize fuzzy parameters and produce final uncertainty maps.
- Integrate classification and coregistered imagery into the data cube structure.
- Perform validation using fuzzy confusion matrices and field/reference data.
- Write report, prepare manuscript, and finalize technical documentation.

Yearly Deliverables

- Complete image coregistration workflow with validated results.
- Fully functional fuzzy classification module and uncertainty outputs.
- Prototype data cube containing aligned and classified datasets.

- Final report and publication-ready manuscript.