Automatic Detection of Photovoltaic Power Stations in Brazil Using Satellite Imagery and Deep Learning

Introduction:

Brazil has witnessed significant growth in the photovoltaic (PV) power sector over the last decade, driven by abundant solar resources and supportive government policies. As of 2023, Brazil's solar energy capacity surpassed 25 GW, solidifying its position as a major player in the global renewable energy transition. The government's auction system and decreasing PV panel costs have propelled this expansion, making solar energy increasingly competitive with traditional energy sources.

Beyond large-scale solar farms, the country has also seen a notable rise in distributed generation, especially with rooftop solar installations for residential and commercial purposes. Incentives such as net metering policies have contributed to energy savings and independence. However, challenges like grid improvements and better integration of intermittent renewable sources remain. Despite these obstacles, Brazil’s solar market is expected to continue growing, playing a pivotal role in meeting energy demands and advancing climate goals.

Problem Statement:

The growth of photovoltaic power stations in Brazil presents both opportunities and challenges:

- Market Intelligence and Investment Opportunities: Monitoring mid and large-scale PV power plants can offer critical insights into solar capacity and market trends. Investors and energy companies can leverage this data to identify expanding markets and refine investment strategies.
- Competitor Analysis: Regular updates from satellite data allow companies to track competitors' solar assets.
- Energy Supply Monitoring: Governments and energy regulators can use PV installation data to better plan for grid management and policy adjustments by accurately tracking solar power capacity and supply.

Automatically detecting PV power plants allows users to monitor, identify and observe differences over time on large extensions of territory.

Datasets:

As mentioned in the previous capstone delivery (link: Capstone GitHub), two datasets are available for this project:

- Sentinel-2 – MSI – Level-2A:
    - 10-meter spatial resolution, suitable for detecting medium to large solar installations.
    - Surface reflectance data corrected for atmospheric effects, improving model accuracy.
    - Free and regular access with a 16-day revisit time.

Data sources: Brazil Data Cube and/or Google Earth Engine. Depending on project needs, one of these sources will be chosen.

Problem to Solve:

This project aims to implement a Supervised Learning Model for segmentation based on deep learning. The key milestones include:

- Baseline (Optional):
    - Use a simpler neural network.
    - Experimental approach: Apply histogram filtering based on specific bands' reflectance.
- Model:
    - A Computer Vision Neural Network for segmentation using supervised learning.
    - A very successful model for semantic segmentation is the Unet. This model was published in 2015 and many modern models are essentially refinements of this model (e.g. Unet++ and RSUnet).
- Training:
    - The first approach involves using a pre-existing training set with PV imagery segmentation, employing masked arrays where input image pixels serve as ‘features,’ and the binary mask indicates the presence of PV panels (‘target’).
    - A secondary approach consisting in creating from scratch a dataset is tenting, although the time effort involved increased considerably.

      We will evaluate the most convenient approach.

- Testing:
    - Subsequent tests will expand to different regions in Brazil. Testing will begin with a smaller surface area and gradually extend to a larger one.
- Evaluation Metrics:
    - Accuracy, sensitivity, significance, ROC-AUC, and F1-score will be calculated using a confusion matrix. Intersection over Union (IoU or also known as Jaccard Index) is also prominent for semantic segmentation.

Computational Resources:

The computational resources for this project will evolve depending on its progress. Initial stages will be executed on a local computer with GPU support. For larger datasets or model architectures, cloud computing resources may be required. This aspect will be further refined in collaboration with my mentor, Artem.

Consulted sources:
https://medium.com/@robmarkcole/a-brief-introduction-to-satellite-image-segmentation-with-neural-networks-33ea732d5bce