IITGN's Summer Research Internship Project (SRIP Project Number: IP0NB0000019)

About the Lab

Sustainability Lab focuses on utilizing machine learning and sensing technologies to address computational sustainability challenges, particularly in smart buildings, energy disaggregation, air quality, and healthcare. [https://sustainability-lab.github.io/]

Alumni Experience:
Read about the Awards and Alumni experience.

Past SRIP interns in action.

- Devodita Chakravarty [SRIP 2024] won the Bhalodia-Khetan Summer Research Excellence Award for the project titled "ML for Sustainability: Satellite Data Preprocessing for Detecting Pollution Sources Using Computer Vision.' The award includes a cash prize of ₹50,000 and a Certificate of Excellence"

Procedure for Application

- Step 1 : Please fill out the form on the official IITGN SRIP portal. Take note of your InternID.
- Step 2 : Please fill the Google Form with the task shared in this document.
- If in doubt, contact the mentor to learn more about the task. All submission needs to be made in the form of a github repo.
- Number of openings : 0 - 8.

Large-Scale Object Detection and Compliance Monitoring with Geospatial Data

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Pitch

Air pollution and environmental non-compliance remain critical global challenges, requiring efficient monitoring solutions. Traditional survey-based methods for tracking pollution sources, such as brick kilns, are often costly, labor-intensive, and time-consuming. The integration of computer vision and machine learning with satellite imagery offers a scalable approach to automating object detection and compliance monitoring. Our research leverages geospatial data to track technological adaptations

and regulatory compliance across various sectors. By utilizing remote sensing techniques, we can enhance the detection of environmental and industrial activities, contributing to effective policy enforcement, pollution control, and sustainable development. Additionally, advanced satellite imaging, including SAR and optical data, helps overcome challenges like cloud cover, ensuring more accurate monitoring and analysis. This approach aims to transform large-scale environmental assessment, providing actionable insights for governments, researchers, and policymakers in their efforts toward better resource management and compliance enforcement.

Recent Literature: (Must Read before applying)
1. Space to Policy: Scalable Brick Kiln Detection and Automatic Compliance Monitoring with Geospatial Data
2. Scalable Methods for Brick Kiln Detection and Compliance Monitoring from Satellite Imagery: A Deployment Case Study in India

Expected skills

- PyTorch
- Open-CV
- Machine Learning

Project 1: Super-Resolution of Satellite Images

- Generating high-resolution satellite imagery from low-resolution inputs using deep learning techniques (e.g., GANs, CNNs) to improve environmental monitoring and object detection.

Mentor: Rishabh Mondal 📧rishabh.mondal@iitgn.ac.in

Project 2: Benchmarking Brick Kiln Detection Models

- In this project, we evaluate various machine learning models for brick kiln detection using Sentinel-2 imagery. Our objective is to systematically compare these models in terms of their accuracy, computational efficiency, and generalization capabilities across different regions. We will assess key performance metrics such as precision, recall, and mean average precision (mAP). By benchmarking these detection models, we aim to identify the most robust and efficient approach, ultimately supporting more reliable brick kiln monitoring and regulatory enforcement.

Mentor: Rishabh Mondal 📧rishabh.mondal@iitgn.ac.in

Project 3: Tracking Brick Kiln Technology Adaptation

We analyze historical satellite imagery to monitor changes in brick kiln technology adoption, assess compliance with regulatory measures, and evaluate the environmental impact over time. Our objectives include:

- Identifying shifts in kiln designs and technological improvements.
- Assessing how these changes align with regulatory compliance.
- Evaluating the correlation between technology adaptation and environmental outcomes, such as emissions and land-use changes.

Mentor: Rishabh Mondal 📧rishabh.mondal@iitgn.ac.in

Project 4: Crop Classification based on temporal signatures of high resolution Optical and SAR images

Crop classified maps are one of the most necessary inputs for developing crop models and yield forecasting. The temporal signatures of crops obtained from optical satellite data are unique and act as a powerful feature to distinguish these but the appearance of clouds makes it harder to guess the crop in fields under clouds. However, the SAR data can penetrate the clouds and fog;

therefore can help in distinguishing the crops. Our target is:

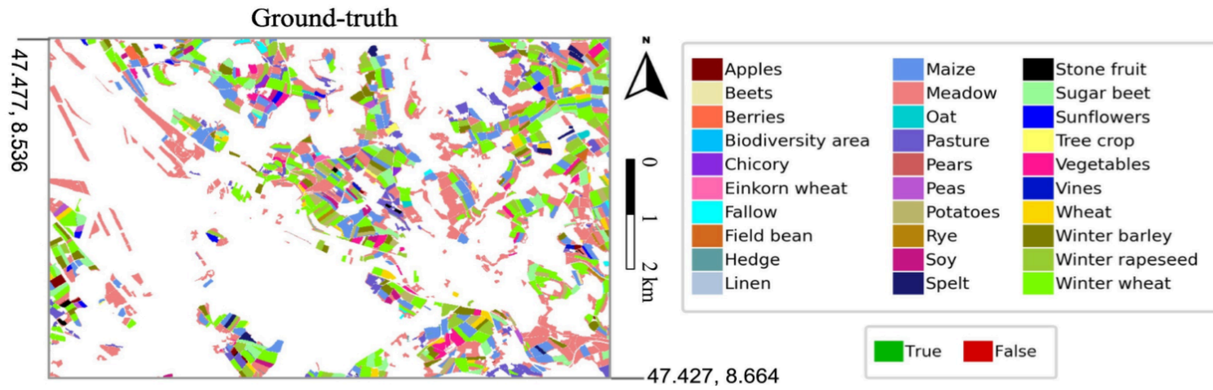

Fig: Example Crop Classification Map (Source: Internet)

- Develop a methodology that uses temporal signatures of optical and SAR data to build regional crop maps provided limited training samples.

Prerequisites

- Working knowledge of Python, Machine Learning, and Deep Learning frameworks.
- Basic knowledge of handling satellite data using Python
- Interest and willingness to go deeper in application of AI algorithms to solve real world challenges

Reading Material

- Basics of Remote Sensing (for basic scientific understanding of satellite data)
- Handling satellite data using python
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Mentor: Ujjwal K. Gupta [24330048@iitgn.ac.in]

Project 5: VayuBuddy: An Air Quality ChatBot with CodeGen LLMs

Pitch

Nearly 6.7 million lives are lost due to air pollution every year. While policymakers are working on the mitigation strategies, public awareness can help reduce the exposure to air pollution. Air pollution data from government-installed-sensors is often publicly available in raw format, but there is a non-trivial barrier for various stakeholders in deriving meaningful insights from that data. In this project, we are developing a CodeGen LLM based system which acts on air quality data based on user query and returns analysis, answers and visualizations.

Reading Material

VayuBuddy: an LLM-Powered Chatbot to Democratize Air Quality Insights

Project 6: Active Learning for Optimal Air Quality Sensor Placement

Pitch

Air pollution is a global problem and has a severe impact on human health. Fine-grained air quality (AQ) monitoring is important in mitigating air pollution. However, existing AQ station deployments are sparse due to installation and operational costs. In this project, we plan to use active learning techniques to recommend optimal locations to deploy air quality sensors.

Reading Material

Environmental Sensor Placement with Convolutional Gaussian Neural Processes
https://github.com/patel-zeel/patel-zeel.github.io/blob/master/_publications/papers/SubSetML21.pdf

Selection Task (Mandatory for all projects)

Submission Date: 28.02.2025

Form: Click Me

Doubts Clearance: Rishabh Mondal 📧rishabh.mondal@iitgn.ac.in

Dataset:

- This data is uploaded to Google Drive: Images (Use 31 cm native resolution images with 416x416 sizes): https://drive.google.com/drive/folders/13QfMQ-7OdWKw-LR8DmypKwSHtI0Hk2wh?usp=sharing
- Labels and README: https://drive.google.com/drive/folders/13QfMQ-7OdWKw-LR8DmypKwSHtI0Hk2wh?usp=sharing
- Label Description: https://figshare.com/articles/dataset/Solar_Panel_Object_Labels/22081091
- Annotation Format: MS-COCO
- Annotation Type: Horizontal Bounding Boxes (HBB)

Data Exploration and Understanding

1. Dataset statistics
   a. How many instances of solar panels are present in the dataset?
   b. Compute and show the value counts of labels per image. E.g., X images have 0 labels, Y images have 1 label, … and so on.

2. Calculate the statistics of the area of solar panels in meters (Read label readme carefully for this question)
   a. What method was used to compute the area (in meters) for a single instance?
   b. What is the mean area and standard deviation?
   c. Plot the histogram of areas. What do you observe?

Implementing the Fundamental Functions

1. Write a function to compute IoU (Intersection over Union) https://pyimagesearch.com/2016/11/07/intersection-over-union-iou-for-object-detection/ between two axis-aligned bounding boxes specified in the Ultralytics YOLO format. You MUST use the `shapely` library [https://pypi.org/project/shapely/] and its functionalities to write your function. Show that your function provides the same or similar answer as IoU computed using \`supervision\` library

2. Write a function to compute Average Precision (AP)
   a. Use Pascal VOC 11 point interpolation method to implement the function
   b. Use COCO 101-point interpolation method to implement the function

c. Use Area under Precision-Recall Curve (AP) method to implement the function

d. Randomly generate 10 images of size 100x100. Randomly generate 10 ground truth boxes of size 20x20 and 10 predicted boxes of size 20x20 in each image. Assume there is only one class of objects. Compare the AP50 (Average Precision at IoU 0.5) computed by 3 of your methods

Model building and evaluation

Split the data into 80-20 train-test split. Use 10% of training data as validation.

1. Use any model from Ultralytics like YOLO to train the object detection model. Show that validation loss is converged.

2. Predict solar panels using the trained model. Visualize the ground truth and predicted bounding boxes on 3-4 random samples from the test dataset. Use appropriate color schemes to differentiate between ground truth and predicted labels.

3. Use `supervision.metrics` functionality from `supervision` library to compute the following metrics.
    a. Compute mAP50 with supervision and compare with your implementation. What do you observe

    b. Create a table of Precision, Recall and F1-scores where rows are IoU thresholds [0.1, 0.3, 0.5, 0.7, 0.9] and columns are confidence thresholds [0.1, 0.3, 0.5, 0.7, 0.9] (Hint use supervision.metrics.ConfusionMatrix to get the confusion matrix and get TP, FP and FN from it to compute the P, R and F-1)

🙂Best of luck 🙂