SCHOOL OF COMPUTATION, INFORMATION AND TECHNOLOGY — INFORMATICS

TECHNISCHE UNIVERSITÄT MÜNCHEN

Master's Thesis in Data Engineering & Analytics

Thesis Proposal

Enhancing Photovoltaic Detection Using Generative AI for Super-Resolution Satellite Imagery

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Abstract

The expansion of photovoltaic (PV) installations calls for efficient systems to monitor and evaluate their distribution and performance. High-resolution aerial imaging provides precise detection but is highly inaccessible in terms of availability and expense. In contrast, low-resolution satellite imagery is abundant but insufficient for accurate PV detection due to its low geographic resolution. This thesis suggests using generative artificial intelligence (AI) models to produce synthetic super-resolution (SR) images from low-resolution satellite data. The goal is to improve PV detection accuracy while lowering the costs associated with collecting high-resolution imagery. Geographically, the study will focus on select areas of Germany with high-resolution aerial and low-resolution satellite photographs available to confirm the proposed method's effectiveness.

Contents

1 Introduction

1.1 Background

Photovoltaic (PV) detection through remote sensing is significant due to its potential for efficient monitoring and assessment of solar installations. High-resolution aerial imagery, such as 40 cm resolution images, provides precise detection results; however, this type of imagery is often limited in availability and expensive, making it impractical for widespread use across various regions. Conversely, satellite imagery, available abundantly and at a lower cost, typically suffers from lower resolution (e.g., 10 m resolution), which poses challenges for accurate PV detection.

Recent advancements in generative AI, particularly in super-resolution techniques like Generative Adversarial Networks (GANs), ResNet, and Super-Resolution Convolutional Neural Networks (SRCNN), offer promising solutions. These models can enhance the resolution of images, potentially bridging the gap between low-resolution satellite data and the requirements for accurate PV detection.

1.2 Problem Statement

The main challenge addressed in this thesis is the limitation posed by low-resolution satellite imagery for accurate PV detection. There is a need for a cost-effective method to enhance the resolution of readily available satellite images to match the detection capabilities of high-resolution aerial imagery.

1.3 Objective

The primary goal is to demonstrate the feasibility and effectiveness of using generative AI to produce high-quality super-resolution images from low-resolution satellite imagery, focusing on different regions in Germany where both high-resolution aerial and low-resolution satellite images are available.

2 Methodology

The project will start with acquiring and preparing 40cm resolution aerial pictures and 10m resolution satellite images for specific German locations. Advanced generative AI techniques will be used to create synthetic SR images from low-resolution satellite data. These generated SR pictures will then be assessed using standard image quality metrics. PV segmentation will be applied to both the original low-resolution and synthetic SR pictures. By comparing these segmentation results, the study aims to validate the cost-effectiveness of synthetic SR images as a practical, cost-effective, and accessible alternative to high-resolution aerial imagery for PV detection. This highlights the potential of generative AI in improving remote sensing applications for renewable energy monitoring.

2.1 Research Review

A comprehensive literature review will be conducted to understand the current state-of-the-art in super-resolution techniques using generative AI, PV detection methods, and applications in remote sensing.

2.2 Preprocessing and Data Preparation

- Collect 40 cm resolution aerial images and corresponding 10 m resolution satellite images for selected regions in Germany.
- Align images spatially and temporally to ensure consistency.
- Normalize and resample data as required for model compatibility.

2.3 Generative ML Model Development

- Implement and train generative models such as GANs (e.g., SRGAN), ResNet, and SRCNN.
- Experiment with different architectures to optimize performance.

- Use high-resolution images as ground truth and low-resolution images as input.
- Employ loss functions suitable for super-resolution tasks.

2.4 Production of Super-Resolution Images

Generate synthetic super-resolution images from the low-resolution satellite data using the developed models.

2.5 Define Evaluation Metrics

Define appropriate metrics to evaluate the performance of the ML model, such as PSNR and SSIM.

2.6 Experimental Design and Execution

Design and execute experiments to evaluate the generated super-resolution images, including:

- Quantitative assessment using the defined metrics.
- Qualitative visual inspection.

2.7 Analysis and Results

Use the super-resolution images to detect PV installations by applying state-of-the-art PV segmentation algorithms.

2.8 Discussion and Interpretation

Discuss the implications of PV segmentation using super-resolution images derived from low-resolution satellite data, including effectiveness and potential limitations.

2.9 Recommendations and Conclusion

Summarize key findings, provide recommendations for future research, and conclude the study.

3 Timeline

This timeline constitutes a tentative outlook for this thesis. The tasks are subject to change based on the research progress and requirements.

Table 3.1: An overview of the planned thesis timeline.

Task	**Duration**
Literature Review	Month 1
Data Acquisition and Preparation	Month 2-3
Experimental Design and Execution from Literature	Month 4-5
Analysis, Reports, and Overall Results	Month 6

4 Conclusion

This thesis seeks to address a significant gap in the field of remote sensing for renewable energy applications. By enhancing low-resolution satellite imagery using generative AI, the research has the potential to revolutionize PV detection processes, making them more accessible and cost-effective.