Title: Enhancing Solar Panel Analytics through RGB-Multispectral Decomposition and Chebyshev and Fourier Networks

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Abstract

Solar panels are pivotal in renewable energy generation, contributing significantly to global sustainable development and reducing greenhouse gas emissions. Numerous studies have highlighted their role in decreasing reliance on fossil fuels and combating climate change. However, the widespread adoption of solar technology brings challenges in maintaining efficiency due to faults like cracks, physical damages, bird droppings, dust accumulation, and shadowing. Manual inspection is time-consuming, labor-intensive, and costly, underscoring the need for autonomous and efficient fault detection solutions.

This Ph.D. thesis presents an **end-to-end pipeline** for solar panel analytics that leverages unmanned aerial vehicle (UAV) imagery for automated enhancement, segmentation, fault detection, and classification. The proposed system addresses the limitations of existing solutions by performing effectively in resource-constrained environments—such as UAVs—and handling low-resolution data while maintaining high accuracy. To achieve these goals, the following key components will be developed:

1. **Unsupervised Enhancement Network Based on Retinex Theory**: A novel network that enhances UAV-captured images without supervision, improving visual quality for better analysis under varying lighting conditions.
2. **Multispectral Decomposition and Chebyshev Transformation-Based Segmentation Network**: An innovative network designed with minimal trainable parameters, optimized for fast and accurate segmentation of solar panels using multispectral decomposition techniques.
3. **General Pipeline for Arbitrary Salient Object Detection**: A versatile pipeline that integrates multispectral decomposition and frequency domain analysis, extending its applicability to detect various salient objects beyond solar panels.
4. **Efficient and Lightweight Fault Classification Network**: This network, which incorporates learnable **Slant** and Fourier transformation blocks, effectively classifies identified faults in solar panels with reduced computational complexity.

Evaluation of benchmark datasets will demonstrate superior performance compared to state-of-the-art techniques, utilizing metrics such as precision, recall, F1-score, intersection over union and others. Real-world deployment in scenarios like autonomous vehicles and surveillance systems validates the effectiveness and robustness of the models.

Key Benefits: This research will contribute to developing efficient and autonomous inspection systems for solar panels, aiding in maintaining their longevity and optimal performance.

- The developed models will significantly improve detection accuracy for faults in solar panels by addressing challenges posed by adverse conditions.
- Integration of advanced imaging techniques will ensure robust performance across various environmental conditions, enhancing system reliability.
- Optimized for near real-time applications, the models will facilitate timely and accurate decision-making in critical scenarios.
- The research will advance fields like agriculture, environmental monitoring, and military applications, demonstrating the pipeline's adaptability to diverse domains.

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