Enhancing Intra-Hour Solar Irradiance Estimation Through Knowledge Distillation and Infrared Sky Images

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Introduction

• Solar energy is abundant but intermittent, posing challenges for stability in the global energy system.
• Precise early forecasting is crucial for integrating solar energy seamlessly into power grids.
• Deep learning and computer vision have enabled the development of image-based solar irradiance forecasting models.
• Model compression techniques, like knowledge distillation, have been explored to boost accuracy with minimal computational resources.
• This research introduces a novel knowledge distillation approach for intra-hour solar irradiance estimation, leveraging infrared sky images to enhance a lightweight CNN model.

Dataset

Figure 1. Sample images from the Girasol [1] dataset. Open-cv colormap was implemented for better visualization.

Results

We evaluate our model’s performance by doing a comprehensive analysis of using key metrics such as MSE, RMSE and the number of parameters of each model.

Contribution

• Proposed a novel sigmoid-based knowledge distillation loss function for regression tasks.
• Improved the accuracy of a simple CNN-regression network, minimizing the MSE loss from 3015.63 to 2540.67

Methodology

• Knowledge distillation involves transferring knowledge from a large pre-trained model (Teacher Model) to a smaller, more efficient model (Student Model)
• The student model is trained using a loss function which takes into account both the actual target and the teacher model’s predicted values.
• In our method, we soften our student and teacher logits using a modified sigmoid function stated at Equation (1)
• The total loss is calculated as Equation (2)

Modified Sigmoid loss:

\[ \sigma'(x) = \frac{1}{1 + e^{-\tau x}} \]  
\[ \text{Distillation Equation:} \]
\[ L = (1-\alpha) L_{kh}(Ps,Y) + \alpha L_{mse}(Pt',Ps') \]  
Here,
\[ a, \tau: \text{Hyperparameters} \]
\[ Ps: \text{Student Logs} \]
\[ Y: \text{Actual Target} \]
\[ L_{kh}: \text{Cross-entropy loss} \]
\[ Pt': \text{Softened Teacher Logs} \]
\[ \alpha: \text{Softmax function} \]
\[ Ps': \text{Softened Student Logs} \]

References