INTRA-HOUR SOLAR IRRADIANCE ESTIMATION USING INFRARED SKY IMAGES AND MOBILENETV2-BASED CNN REGRESSION

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The motivation stems from the need to address the challenge of intra-hour solar irradiance estimation. The question arises:

*Can accurate estimates be obtained from sky images?*

- **Solar Irradiance Dependency on Cloudiness:** The solar irradiance on Earth's surface is significantly influenced by cloudiness, leading to short-term fluctuations due to the motion and distribution of clouds\(^1\).

- **Limitations of Common Weather Stations:** Conventional weather stations, equipped with solar sensors, measure total solar irradiance at specific points. However, they cannot provide essential information regarding cloud data\(^2\).

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Contributions

In this study, we utilized infrared sky images and a convolutional neural network to accurately model fluctuations in solar radiation from infrared sky images\(^1\).

- **Enhanced Accuracy with Infrared Imaging**: Utilization of infrared imaging technology to discern temperature variations, contributing to enhanced accuracy in predicting solar irradiance.

- **CNN-Regression**: Our model utilizes efficient CNN regression\(^2\) for real-time solar energy analysis, ensuring swift feature extraction from infrared images

- **Efficient MobileNet v2 Integration**: MobileNet v2\(^3\) is incorporated as a backbone of the CNN-Regression model, for real-time solar energy analysis on mobile devices.

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We employed the Girasol dataset, captured with a sky imager featuring a far infrared camera mounted on a dual-axis solar tracker.

**Girasol Machine Dataset:**

- Originates from the Girasol Machine, a cutting-edge solar forecasting sky imaging Data Acquisition (DAQ) system.
- Combines photos from two light sensors with unique lenses, enriching the dataset with diverse cloud features.

**Solar Tracking and Weather Station:**

- Operates a solar tracking algorithm linked to cameras for sun positioning in infrared (IR) and visible (VI) images.
- Includes a weather station providing comprehensive meteorological data for synchronization with pyranometer.

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In this research, we specifically focused on the IR images from the Girasol dataset.

- We trained our model using a subset (8 December 2017 to 7 January 2018) of the complete dataset.

- The figure shows sample images, for better visualization with colormap.

Sample IR images of size 60 x 80 pixels, that were acquired from the Girasol dataset.
Model Architecture

- Feature Extractor: Utilizes pre-trained MobileNetV2\(^1\) as the feature extractor in the CNN regression model.

- Architecture Details: The input data is processed through the MobileNetV2 backbone, followed by adaptive average pooling and flattening to form a feature vector. This vector is then input into a linear regression head, producing the regression output.

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Training and Evaluation

- Used Mean Squared Error (MSE) during training to assess model fit to the training data.
- Adopted both MSE and Root Mean Squared Error (RMSE) metrics for comprehensive testing evaluation.

<table>
<thead>
<tr>
<th>Batch Size</th>
<th>Epochs</th>
<th>Learning Rate</th>
<th>MSE</th>
<th>RMSE</th>
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<td>50</td>
<td>0.01</td>
<td>281.52</td>
<td>16.18</td>
</tr>
</tbody>
</table>

Demonstration of MSE and RMSE loss

The model's performance on the test data during training
Training and Evaluation

Comparison and Alignment: We compared observed solar irradiance with model predictions, illustrating alignment through measured solar readings (13 February 2018) in the provided figure.

As of February 13, 2018, we display the observed solar radiation in blue and the predicted radiation in red.
Conclusion

In this study, we have introduced an innovative approach for intra-hour solar irradiance estimation, harnessing the potential of infrared sky images and a lightweight architecture based on MobileNet v2.

- Foundation for exploring sophisticated deep-learning architectures
- Enables geographical extensions and improved accuracy in solar irradiance predictions
- Enables efficient integration into edge devices
Thank you

https://github.com/ifran-rahman/solar-irradiance-estimation-dl