Solar Irradiance Nowcasting Using All-Sky Imager Data

Soham Palande and Dr. Ahmed Aziz Ezzat

RUTGERS
Aresty Research Center for Undergraduates

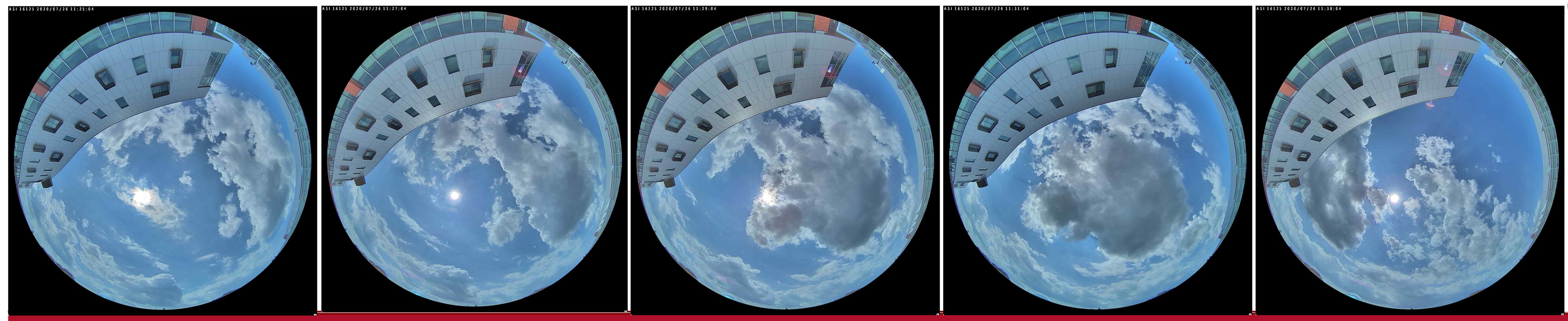
Abstract

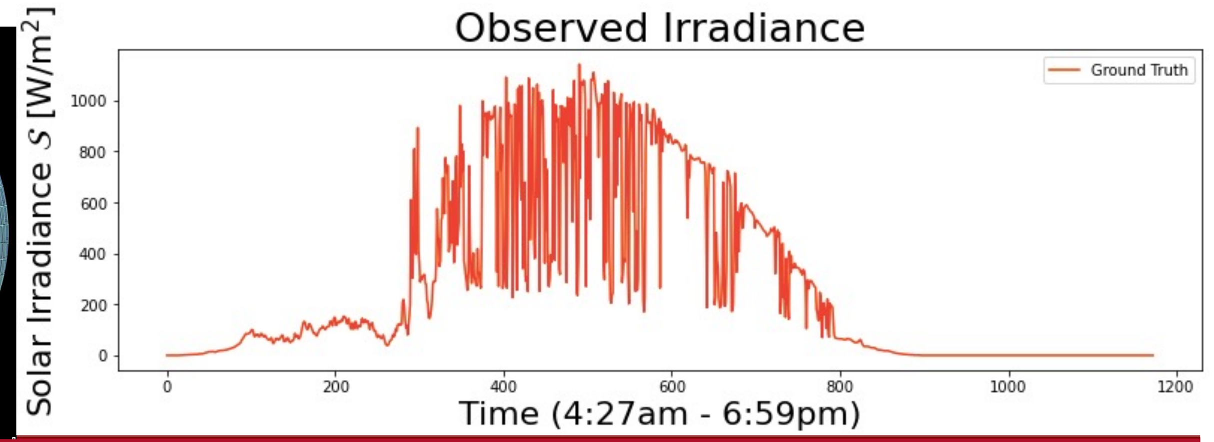
As we continue to look for ways to accelerate our transition to renewable energy, one of the fundamental obstacles to achieving this remains the unpredictable nature of wind and solar energy. Clouds moving in front of the sun and rapid changes in weather conditions cause fluctuations in the measured solar irradiance and cause serious challenges in power grid operation. In this study, we address the unpredictable nature of solar irradiance by using past irradiance measurements and leverage images captured by an All-Sky imager using a Deep Learning Framework to forecast solar irradiance over the short term. We train the model on datasets of varying sizes and show that the models significantly outperform the smart persistence model and state of the art statistical approaches using optical flow techniques.

Goal: To accurately forecast solar irradiance using past irradiance data and all sky images taken from an All-Sky Imager

Background

- The use of Photovoltaic (PV) systems is increasing throughout the world. The inherent fluctuating nature of the PV output causes poses significant challenges in the transition to renewable energy.
- Approaches till date have focus mainly on utilizing past irradiance measurements with a range of auxiliary data such as the Solar Zenith and Azimuthal angles and weather data [1].
- There have been some recent studies which aim to leverage the rich image data from all-sky imagers to forecast Solar irradiance at various short-term intervals using different deep learning architectures such as [2].
- Below are examples of images taken from an All-Sky imager and the irradiance measurements depicting the rapid irradiance fluctuations.





Methods

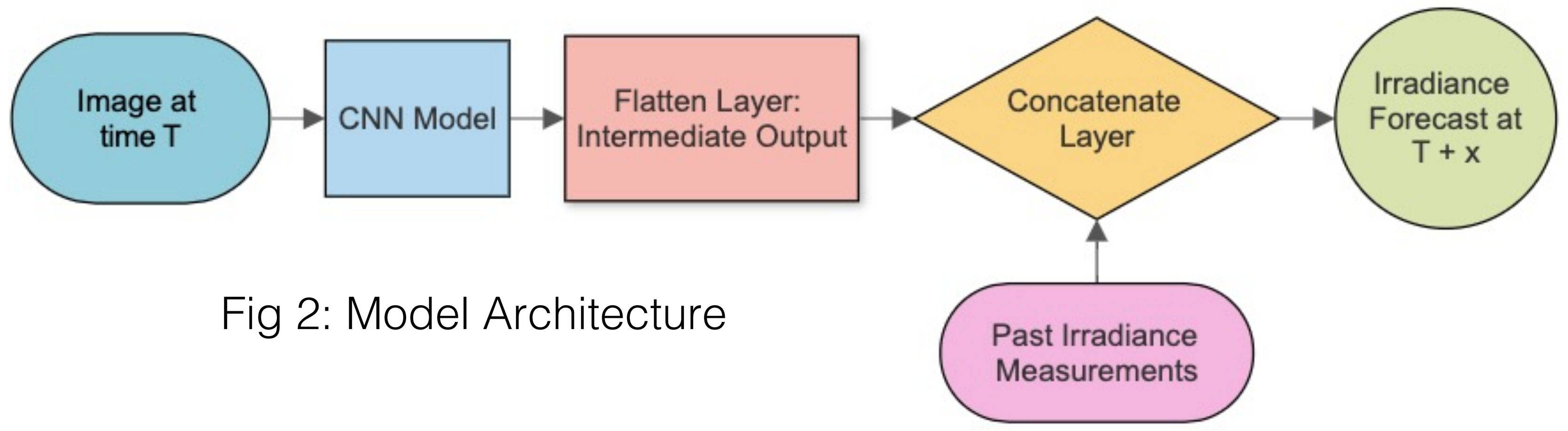


Fig 2: Model Architecture

- The Figure above shows a novel architecture to predict the solar irradiance at time (T+x) where we train separate models for values of x= 0, 5, 10, 15, 20, 30 corresponding to forecasts x min into the future.
- The model takes as input an image at time step T and goes to several layers to produce and intermediate output. Then the model takes in the past 7 irradiance measurements (T, T-1, …T-7) and combines the intermediate output with the past 7 measurements to produce a forecast at time T+x.
- An LSTM layer is used to learn order dependence in the irradiance sequences.

Future Direction

- To implement and train the ConvLSTM model and use a larger training dataset to obtain more accurate results for different types of weather conditions – (clear, partly cloudy, overcast).
- To fine tune/improve the model architecture and to use **sequences of past images** as input along with past irradiance data.

Acknowledgements

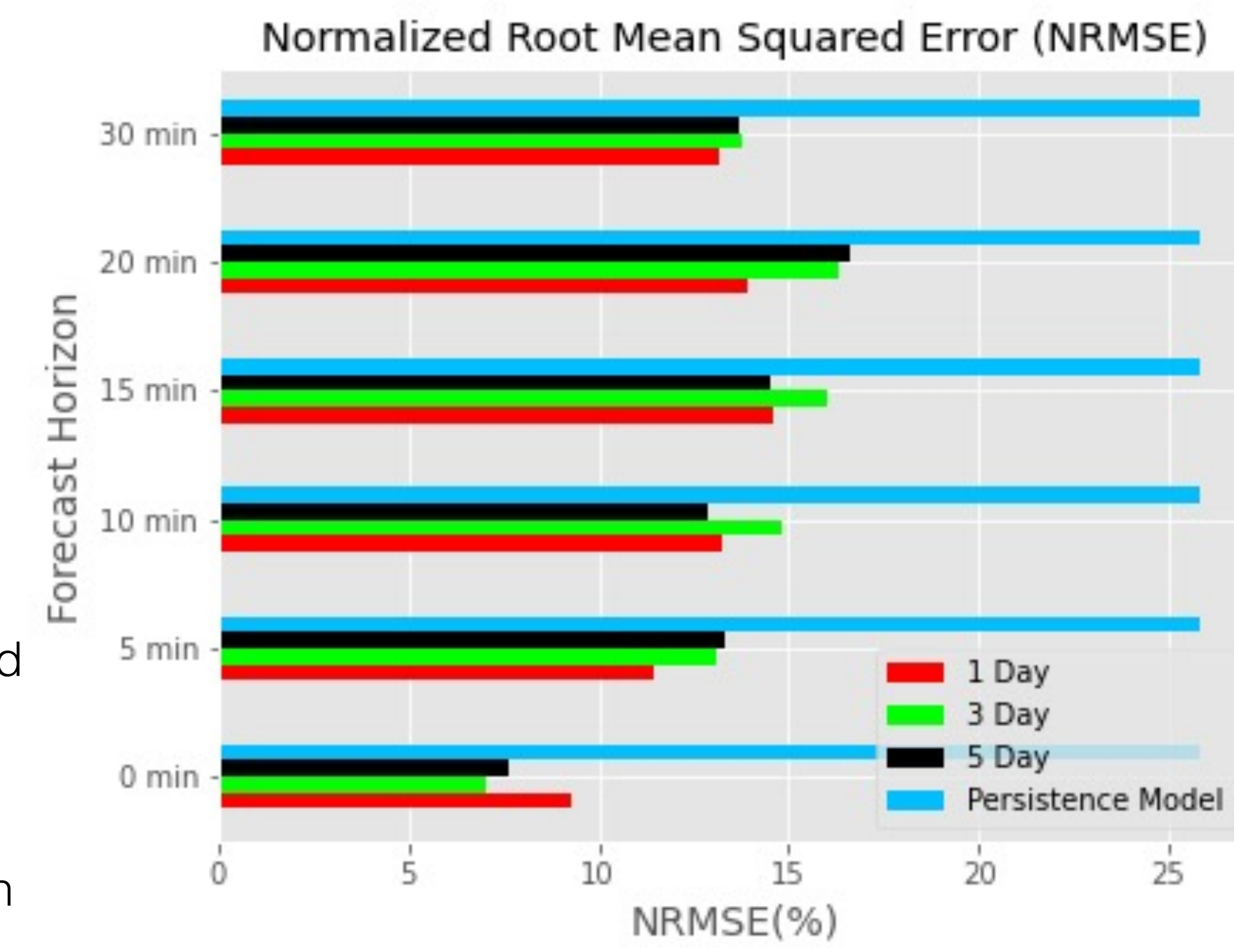
I would like to thank Professor Aziz to allow me to do research under his mentorship. I learned a great deal through this research project and am eager to use my skills on different research projects.

References

1. A. Alzahrani etc, Solar irradiance forecasting using deep neural networks, Procedia Comput. Sci. 114 (2017) 304–313.
2. H. Jiang etc. IEEE Access **8**, (2020) 22235 – 22248
3. Soumyabrata Dev etc. Atmos. Meas. Tech. 12 (2019) 5417-5429

Results

- We trained our models using datasets of images and irradiance measurements taken from an All-sky imager and a pyranometer.
- The models were trained on datasets of 3 different sizes- containing data from 1 day, 3 days and 5 days to test our hypothesis that the models will improve when trained on larger datasets.
- Our results show that our proposed framework significantly **outperforms the Smart Persistence model (industry benchmark)** on all the forecasting ranges – the results are shown in the plot to the right.
- We further test our framework on a completely random day- i.e. on test data that was not part of the dataset the model was trained on. The results are shown below.
- The proposed model also outperforms state-of-the-art statistical approaches and optical flow techniques as shown in [3].
- The results of forecasts at T+10, T+15, T+20 and T+30 are shown below.



All-Sky Imager