Math Matters

Apply It.

The math behind... Predicting Solar Radiation

Some Technical terms used:

Optical flow, fast normalized cross-correlation, phase correlation, nonlinear regression modeling, sequential motion prediction, back-tracking,

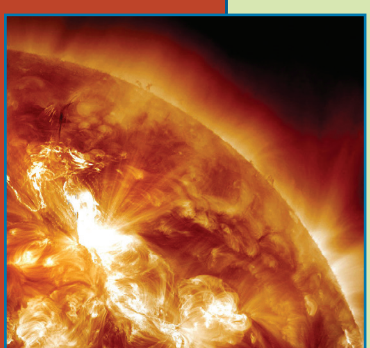
Uses and applications:

Variability of solar energy is the most significant issue for integrating solar energy into the power grid. Solar power volatility could, however, be mitigated if a solar radiation prediction system could provide a time window for grid operators to take necessary actions, such as waking up backup substitute sources.

How it works:

Cloud motion is the primary reason for solar energy output fluctuation. In essence, short-term solar energy output prediction can be simplified by cloud motion estimation. The solar radiation prediction system could use sky images to detect cloud movements, which could, in turn, help estimate future cloud positions over solar panels and subsequent solar radiation fluctuations incurred by cloud transients.

Fast normalized cross correlation is an especially powerful tool for determining optical flow in cloud movements because it combines the accuracy of conventional cross correlation with the efficiency of phase correlation to meet real-time requirements even while providing an effective algorithm. To deal with changes in cloud shape, sequences of consecutive images—as opposed to just two—should be used in the nonlinear regression modeling of cloud motion. This approach is also termed "sequential motion prediction," which consists of three components: 1) back-tracking the same piece of cloud from the current frame to sequences of old frames, 2) learning motion regression models using series of recent motion trends, and 3) predicting the future cloud position from the learned model. Clouds on different layers oftentimes overlap and seem to merge together on the sky images. Multi-layer clouds with different motion patterns are intimately related to wind-field, which is the three-dimensional spatial pattern of winds with different wind speeds. It can be extracted from the previous frames by tracking different cloud-moving patterns used to adjust later predicted cloud images. Once we get the predicted cloud image, a simple linear prediction model with predicted cloud image and solar position as input, it can be used for short term forecasting of solar radiation levels.



Interesting facts:

Over 60 percent of New York City's rooftops are suitable for solar panels, and a large hybrid system connecting solar power and the existing source of power generation could better fulfill the city's demand for electricity, especially at peak power-consumption periods. It is believed that such a systemwill not only reduce greenhouse gasses and other pollutants emitted into air, but also cut down conventional electricity bills for many residential and commercial business owners.

References:

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2) I. Reda and A. Andreas. "Solar position algorithm for solar radiation applications," Solar energy 76, no. 5: 577-589 (2004). http://www.dideas.com/strawbale/sun_position/34302.pdf

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