A Cyber-Physical System Approach for Photovoltaic Array Monitoring and Control

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MOTIVATION

Open problems in PV array management

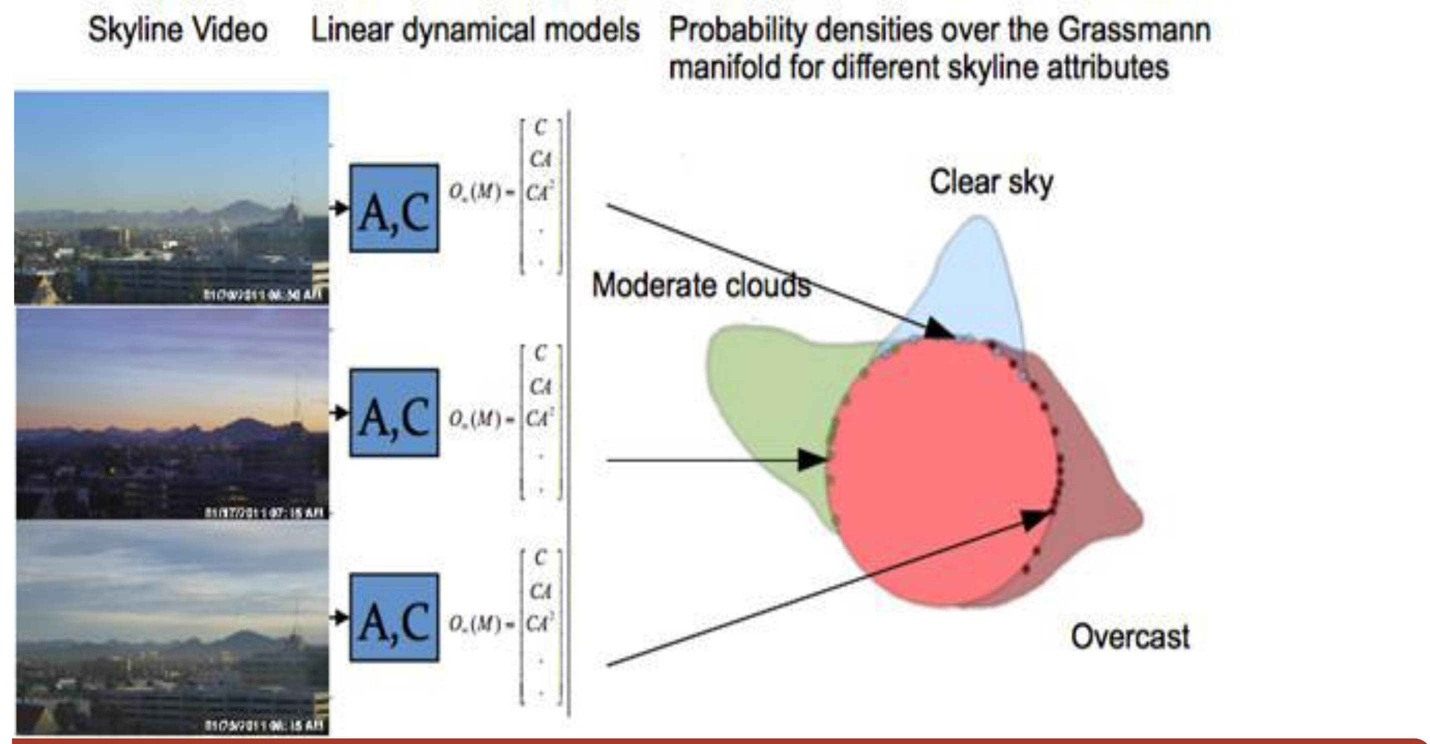
- **Efficiency improvement in solar energy farms;**
- **Faults detection and power output optimization;**
- **Find correlation between observed imagery and PV circuit characteristics;**
- **Skyline feature prediction for better power grid control;**

PROJECT AIM

- **Power Output Optimization by skyline feature prediction using imaging algorithms. [1]**
- **Using ML techniques with sensor fusion data from PV modules for fault detection.[2]**

The SenSIP 18kw (104 panel) experimental facility established at ASU with industry collaborators [3].

PROPOSED ALGORITHM



METHOD

- **f(t) is the sequence of texture and color features extracted from a video of skyline indexed by time.**
- **Evolution of features is marked by**

$$f(t) = Cz(t) + w(t), \qquad w(t) \sim N(0, R)$$
$$z(t+1) = Az(t) + v(t) \qquad v(t) \sim N(0.Q)$$

Where $z \epsilon R^d$ is the hidden state vector, $A \epsilon R^{d*d}$ the transition matrix, $C \epsilon\ R^{p*d}$ the measurement matrix. [4]

- **Parameters of LDS model are best viewed as subspaces formed by columns of observability matrix.**

PRELIMINARY RESULTS

- **A small training set with a few segments as 'clear', 'moderate cloudy', and 'overcast' was used to learn a probability density function on the Grassmannian.**

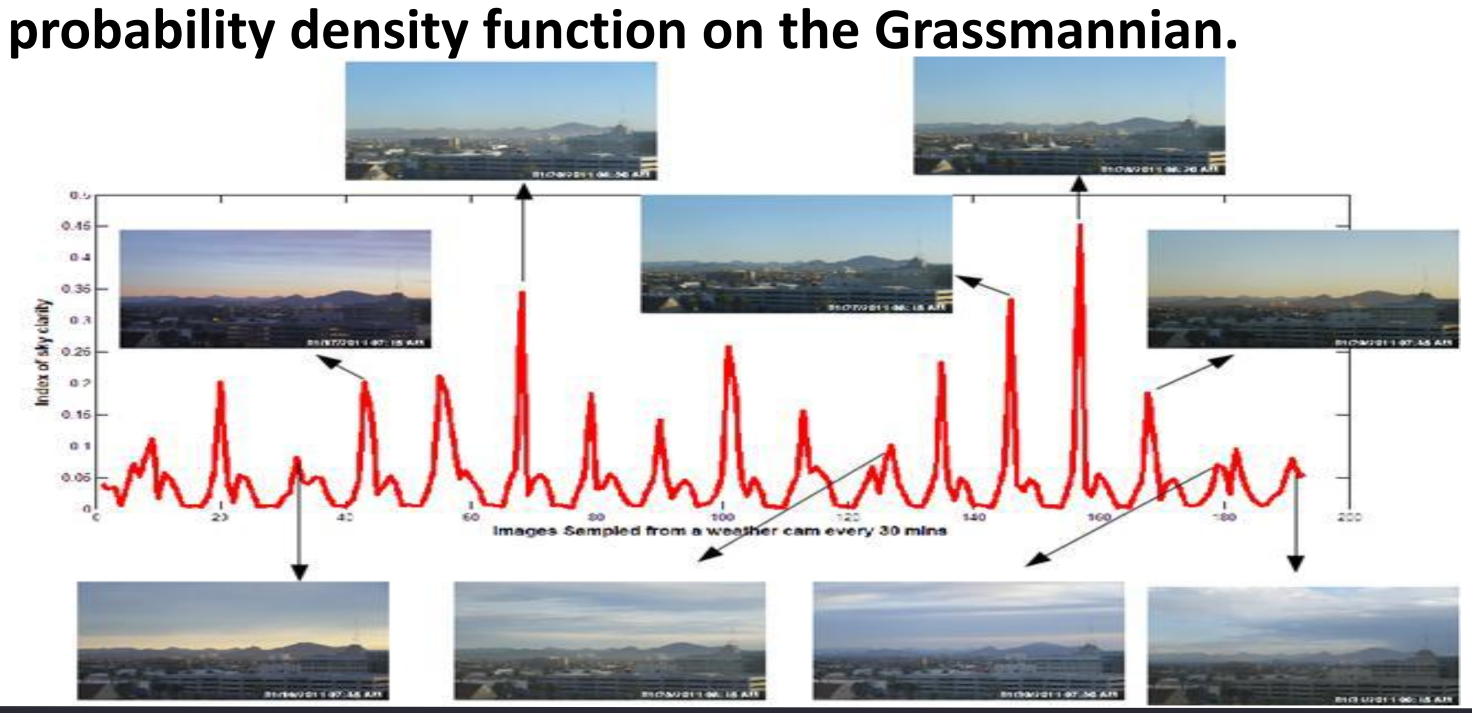
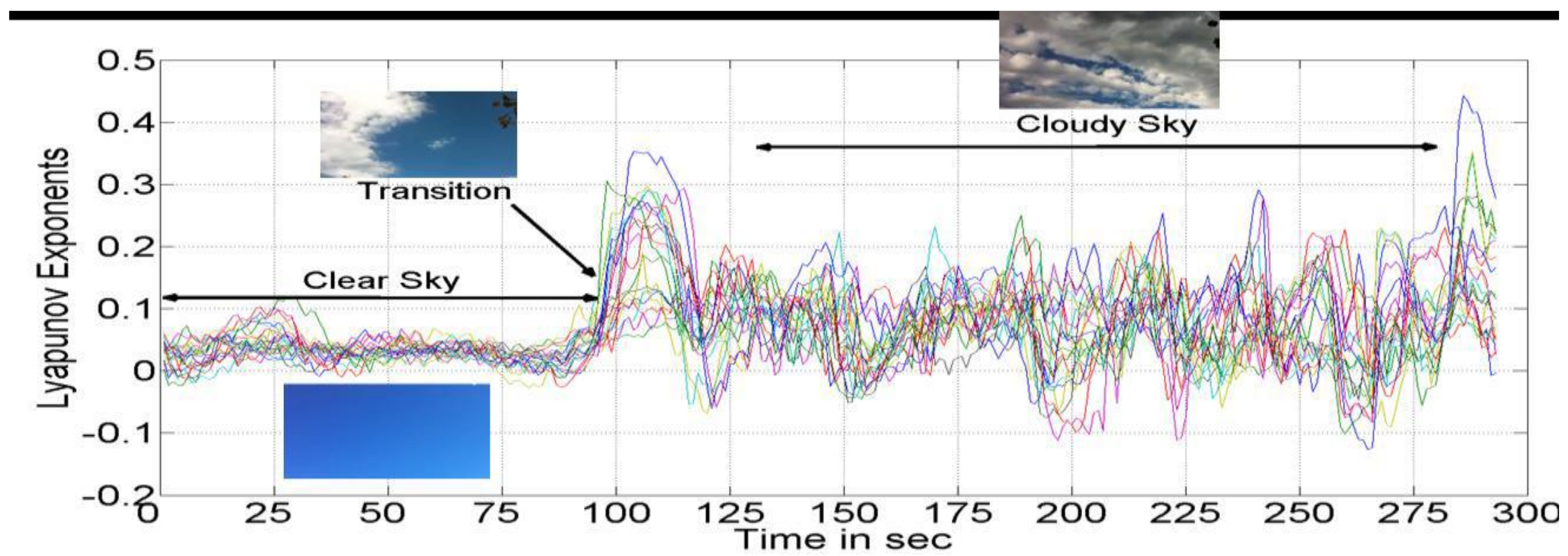


Image-based measures of sky-clarity, an attribute useful for predicting shading. This metric was created from dynamical models of image texture, with a manifold-based metric on dynamical model parameters. Sample images at various times show how the index separates 'clear skies' and 'hazy/cloudy skies'.



Spatio-temporal modeling of sky videos using GIST and largest Lyapunov exponents; with time stamps for clear sky, transition from clear-cloudy sky and cloudy sky.

ONGOING & PLANNED WORK

- **It is possible to develop early warning systems using a small network of horizon viewing cameras.**
- **The transitions obtained using Lyapunov exponents can be used for prediction.**
- **Long term prediction can be performed by reconstructing the hidden phase-space of the true dynamic system using delay embeddings.**

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