Wildfire Mitigation with Advanced Machine Learning and Optimization Techniques

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Outline

- Machine Learning and Advanced Optimization in Smart Grid
- Applications of Advanced Machine Learning and Optimization to Mitigate Wildfire Risks
  - Intelligent Smoke Detection with Mobile Machine Learning
  - Partial Discharge Detection with Deep Neural Networks to Prevent Wildfire
  - Optimal Placement of Remote Cameras for Wildfire Risk Reduction

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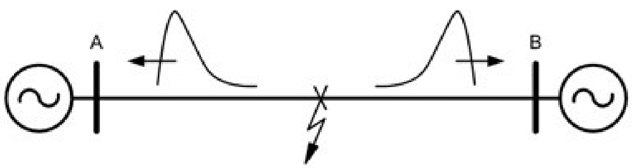
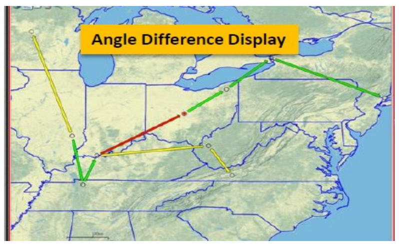
Applications of Advanced Machine Learning and Optimization in Transmission Systems

Electricity Market Applications
Price & Load Forecasting, Algorithmic Trading

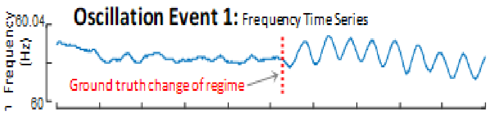
Fault Location
Fault Location using PMU



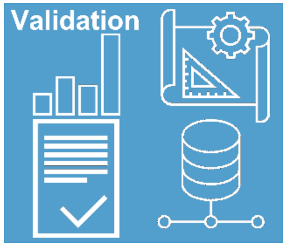
Wide-area monitoring
Phase angle monitoring



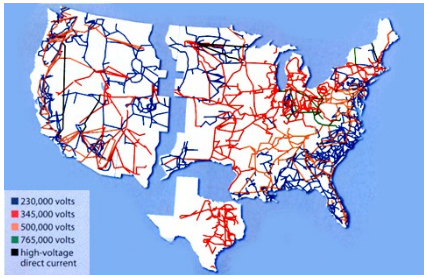
Oscillation detection



Model Validation
Equipment, Generation, Power System



Equipment Monitoring
Identify Equipment/Substation Problems



State Estimation
Linear State Estimation

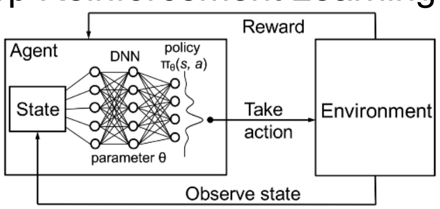
Applications of Advanced Machine Learning and Optimization in Power Distribution Systems

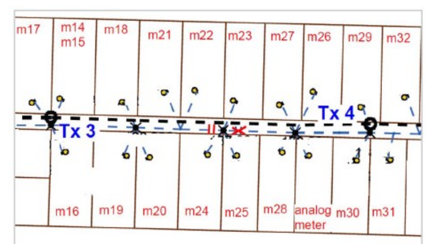
Spatio-temporal Forecasting
Electric Load / DERs – Short-Term / Long-Term

Anomaly Detection
Electricity Theft, Unauthorized Solar Interconnection

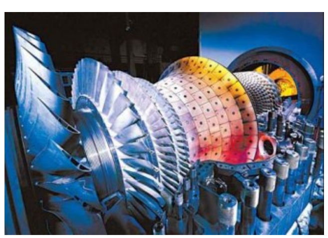
System Monitoring
State Estimation & Visualization

Distribution System Controls
Deep Reinforcement Learning





Network Topology and Parameter Identification
Transformer-to-customer, Phase connectivity, Impedance estimation



Equipment Monitoring
Predictive Maintenance
Online Diagnosis

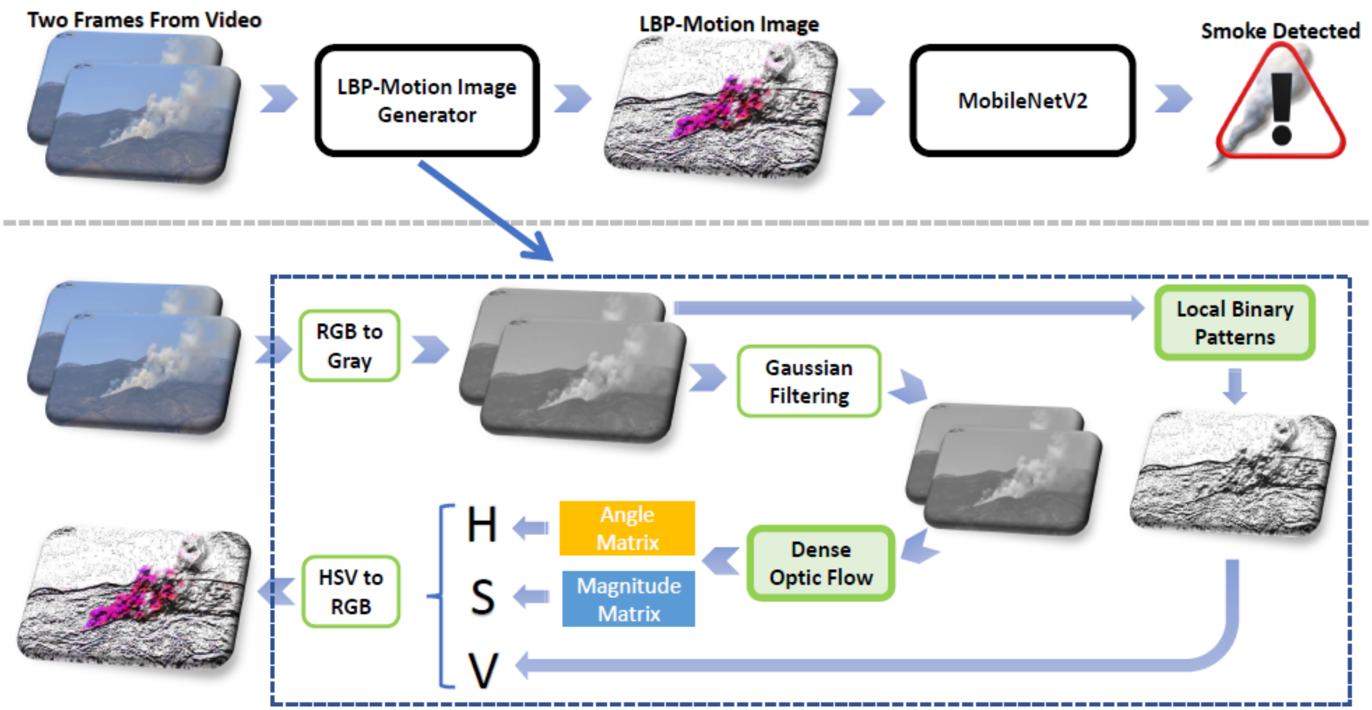
Customer Behavior Analysis
Customer segmentation, nonintrusive load monitoring, demand response

Intelligent Smoke Detection Algorithm

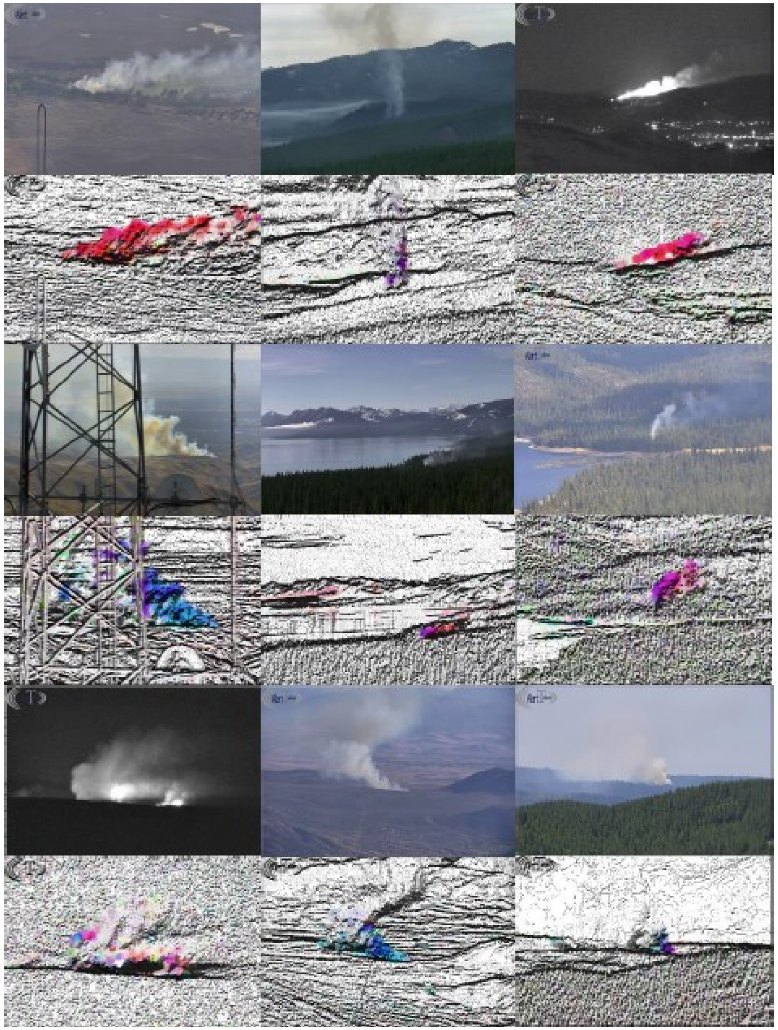
- Increasing installation of wildfire cameras
- Early smoke detection algorithm to mitigate wildfire
  - ***Automatic***, ***high accuracy***, ***lightweight*** (avoid transmitting huge amount of video data)
  - Software and hardware upgrades on wildfire camera (***Smart Wildfire Camera***)

Edge Computing Unit:
Raspberry Pi

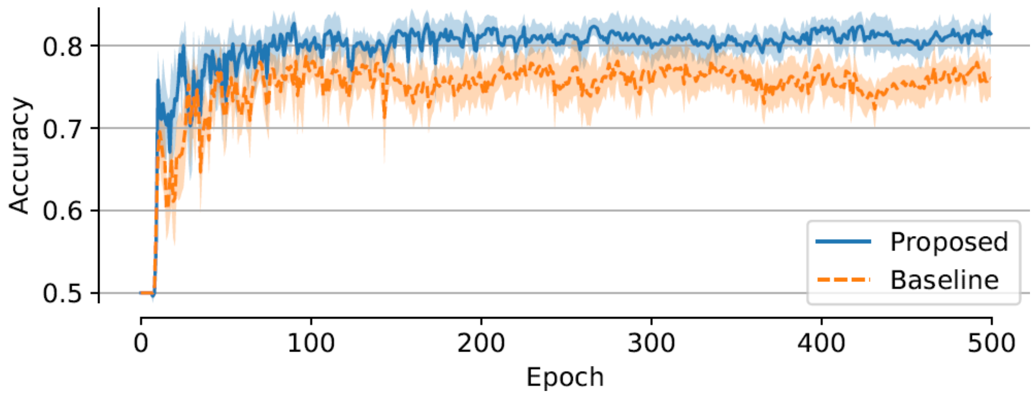
Machine Learning-based mobile smoke detection framework



Testing Results with Real-World Videos



Sample smoke video frames from ALERT Wildfire and corresponding LBP-motion images



Average test accuracy of the proposed & baseline approaches

Neural Network	Detection Time	Memory
MobileNetV2	0.117 ms	8.9 MB
ResNet50	0.237 ms	90.2 MB
DenseNet169	0.367 ms	49.1 MB
InceptionV3	0.216 ms	83.6 MB
InceptionResNetV2	0.492 ms	208.4 MB

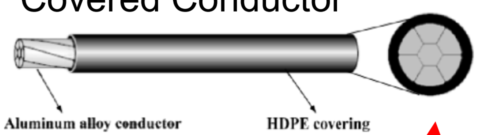
The proposed MobileNetV2 has the shortest detection time the least amount of memory requirement (low cost).

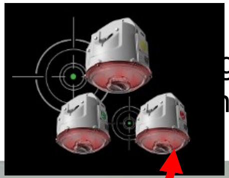
Partial Discharge Detection with Machine Learning

- Upgrading bare conductors does not solve all the problems!
- When vegetation comes in contact with covered conductors partial discharge could occur.
  - Partial discharge is small electrical spark that occurs across the surface of insulating material where the electric field strength exceeds the breakdown strength of insulator.

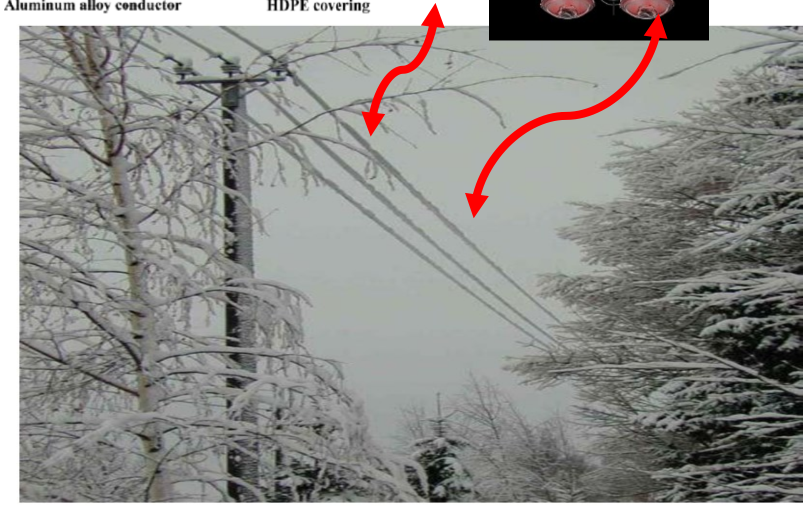
Failed Conductor Due to Partial Discharge

Covered Conductor



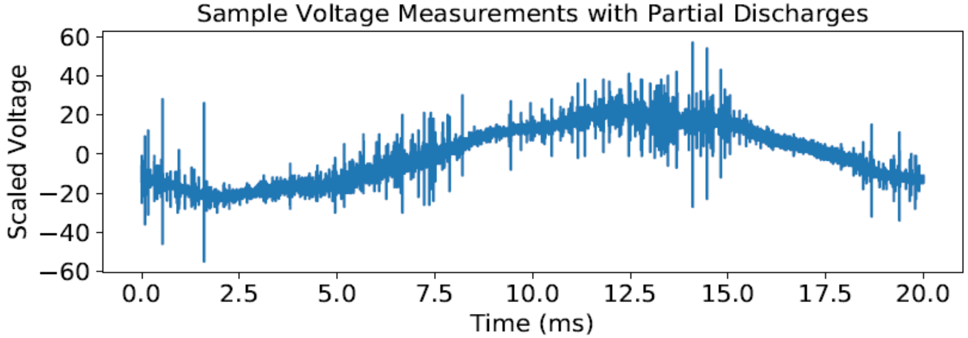


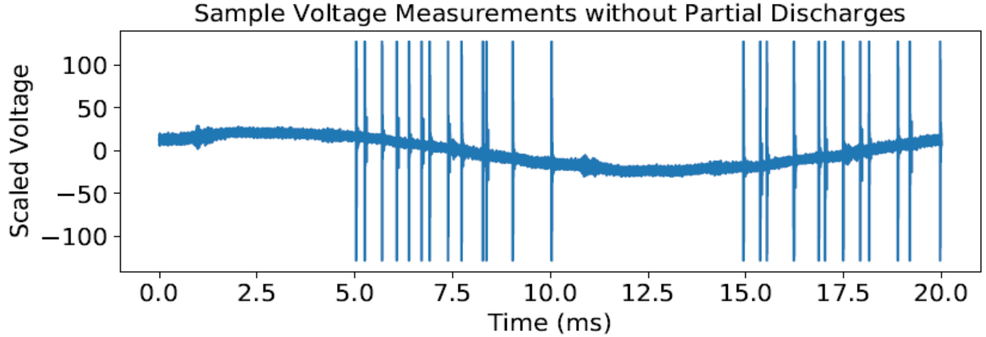
gh Frequency
ne Sensors



Leaning trees on covered conductor lines

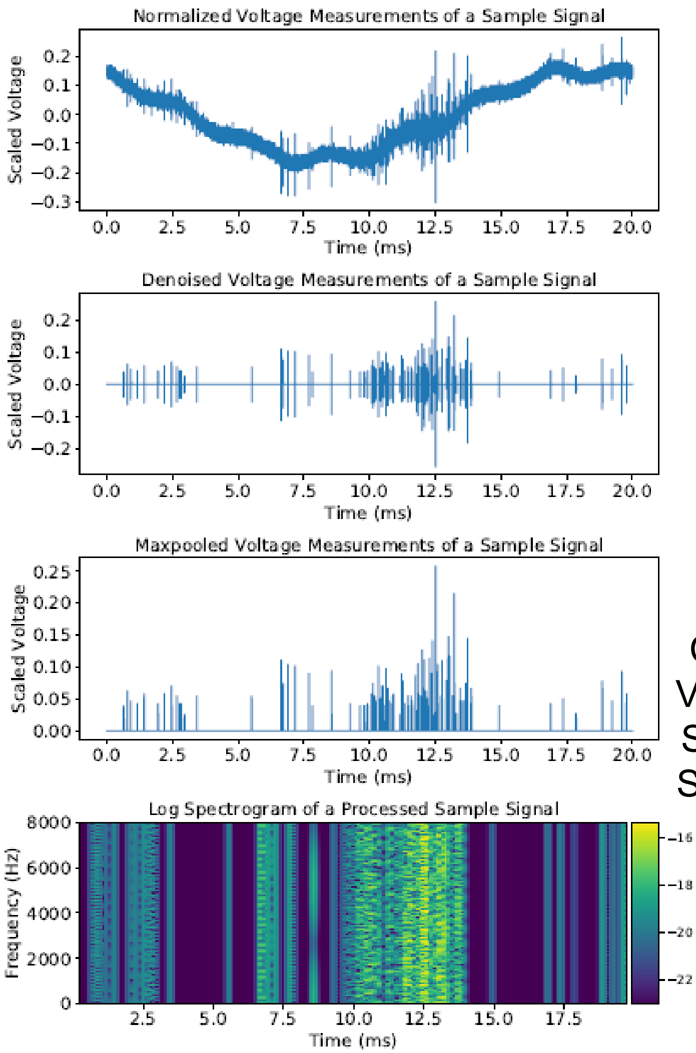
Sample Voltage Measurements with and Without Partial Discharge





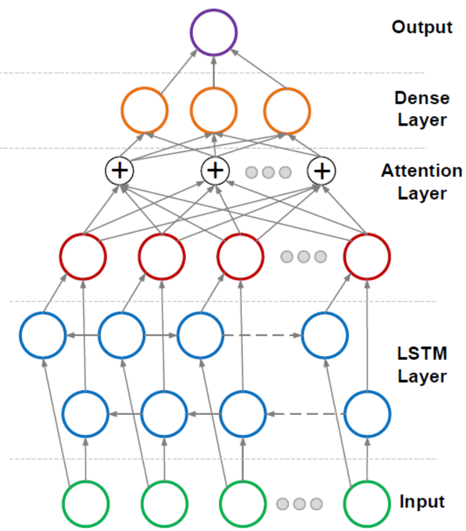
Technical Methods and Testing Results

Stage 1: Signal Preprocessing



Stage 2: Convert 1D Voltage Time Series to 2D Spectrogram

Stage 3: Classify the 2D images corresponding to the voltage time series into groups with and without Partial Discharge



Method	MCC / Accuracy	
	Training	Testing
Random Forest	0.926/0.991	0.712 / 0.968
GBT	0.887/0.986	0.720 / 0.969
Bidirectional LSTM	0.919/0.990	0.621 / 0.955
Resnet18	1 / 1	0.738 / 0.970
VggNet11	0.979 / 0.998	0.744 / 0.968
Resnet18 + VggNet11	1 / 1	0.757 / 0.973

Optimal Placement of Wildfire Cameras

- Goal: Find the optimal placement of wildfire cameras, which achieves the maximum fire risk reduction of the target area given limited budget.
- Optimization Problem Formulation
  - Fire risk of a sub-region can be reduced by a certain percentage if it can be closely monitored by one or more of the wildfire cameras.
  - Magnitude of risk reduction depends on the effective monitoring range of the camera and the distance between the area being monitored and the location of the camera.
  - The cost of wildfire camera installation and maintenance vary significantly by location.
  - The area covered by a wildfire camera depends on the elevation of surrounding terrains.

$$\min_{\{x_i | i \in \mathscr{P}^C\}} \sum_{i=1}^{N} r_i \cdot \max\left(r_{min}, 1 - \sum_{j \in \mathscr{P}^C} p_{ij} s_{ij} x_j \right)$$

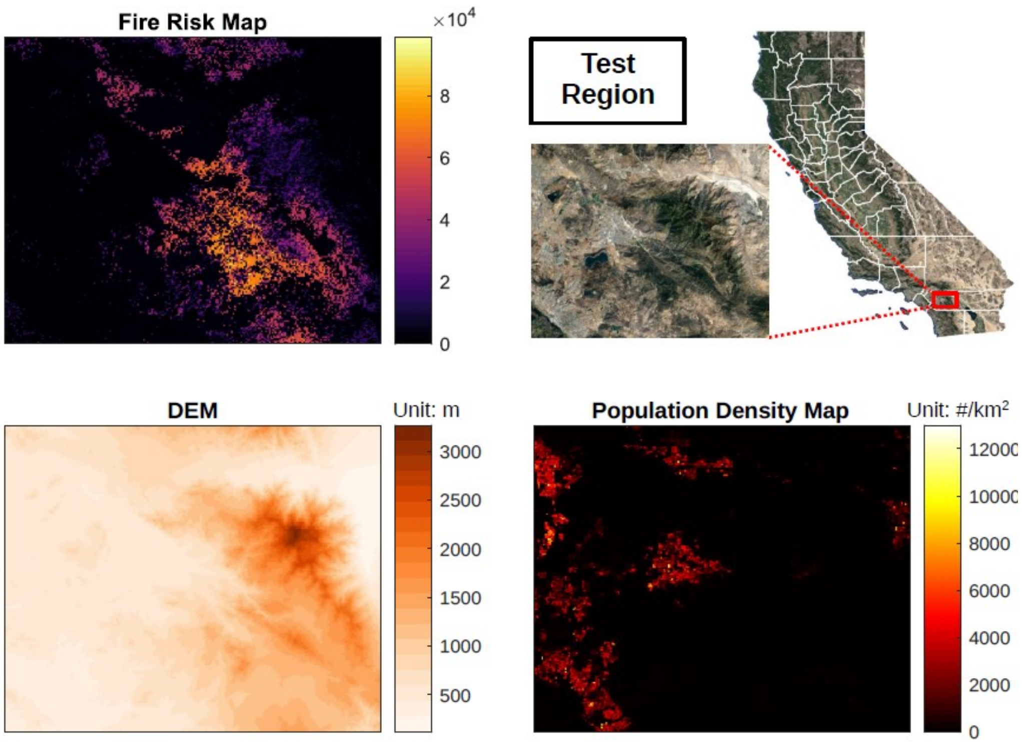
subject to

$$\sum_{i \in \mathscr{P}^C} c_i x_i \leq B$$

$$x_i \in \{0, 1\}, \quad \forall i \in \mathscr{P}^C$$

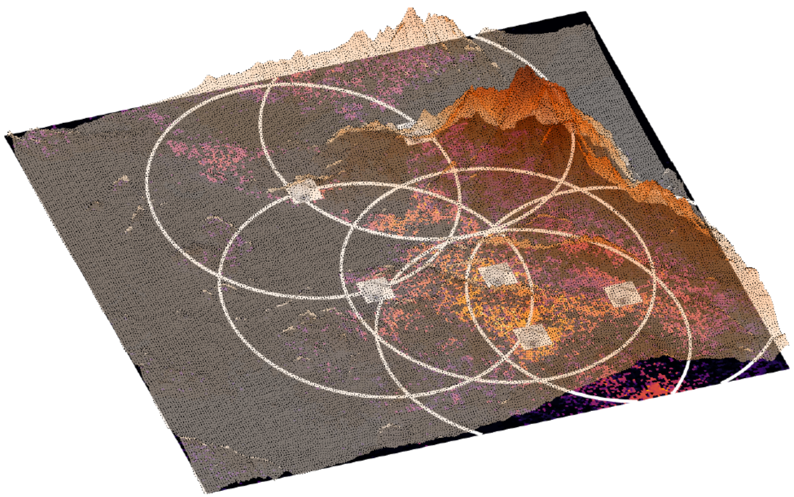
Case Study for Southern California

- Test region: Riverside Country, California.

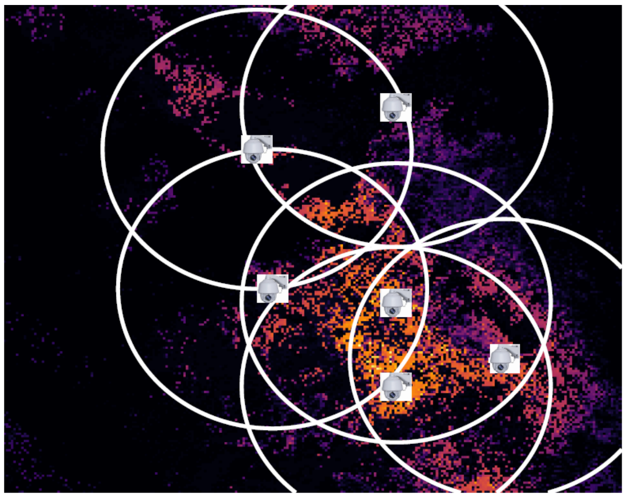


- Fire risk reduction in the test region by 36.28%.
- The net present value of the camera network deployment and maintenance cost is $399,841

Camera placement result with DEM



Camera placement result with fire risk map



Thank You

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1. Jie Shi, Wei Wang, Yuanqi Gao, and Nanpeng Yu, "Optimal Placement and Intelligent Smoke Detection Algorithm for Wildfire-Monitoring Cameras," *IEEE Access*, vol. 8, no. 1, pp. 72326-72339, December 2020.
2. Jie Shi, Wei Wang, Yuanqi Gao, and Nanpeng Yu, "Detection and Segmentation of Power Line Fires in Videos," *IEEE Innovative Smart Grid Technology (ISGT) North America*, pp. 1-5, 2019.
3. Wei Wang and Nanpeng Yu, "Partial Discharge Detection with Convolutional Neural Networks," the *16th International Conference on Probabilistic Methods Applied to Power Systems*, 2020.